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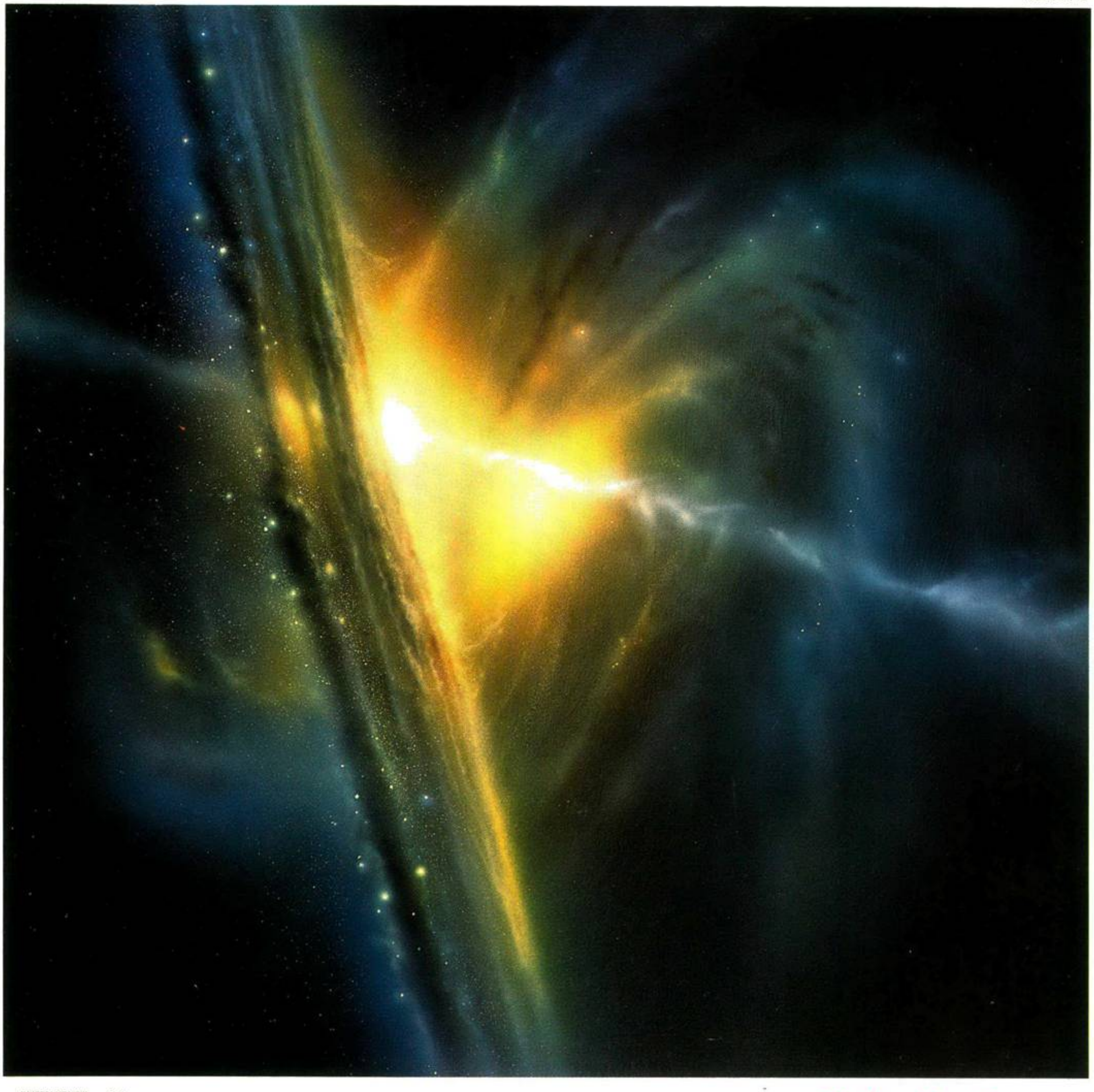
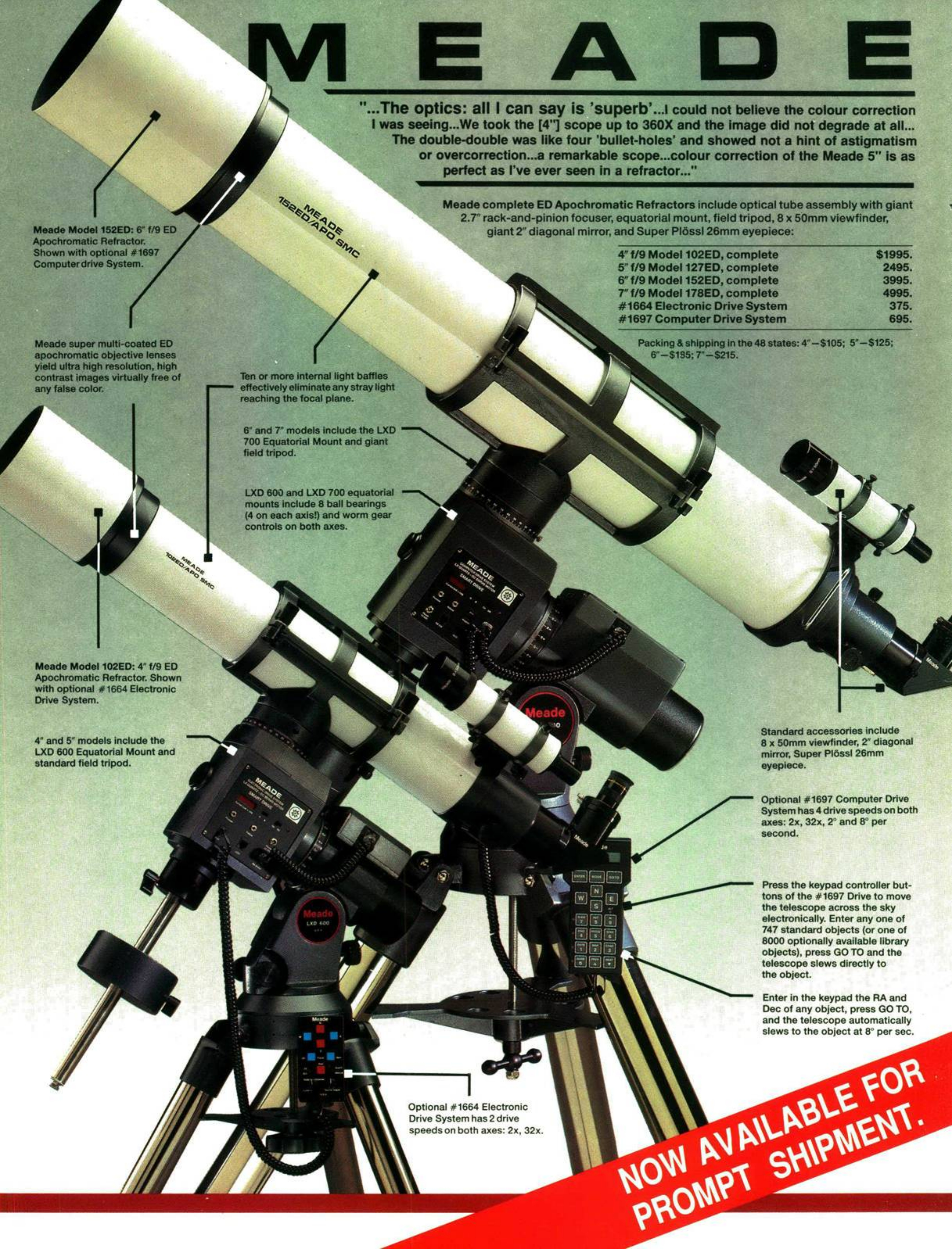


Birth of a Quasar

MEADE

"...The optics: all I can say is 'superb'...I could not believe the colour correction I was seeing...We took the [4"] scope up to 360X and the image did not degrade at all... The double-double was like four 'bullet-holes' and showed not a hint of astigmatism or overcorrection...a remarkable scope...colour correction of the Meade 5" is as perfect as I've ever seen in a refractor..."



Meade complete ED Apochromatic Refractors include optical tube assembly with giant 2.7" rack-and-pinion focuser, equatorial mount, field tripod, 8 x 50mm viewfinder, giant 2" diagonal mirror, and Super Plössl 26mm eyepiece:

4" f/9 Model 102ED, complete	**$1995.**
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#1664 Electronic Drive System	**375.**
#1697 Computer Drive System	**695.**

Packing & shipping in the 48 states: 4"—$105; 5"—$125; 6"—$185; 7"—$215.

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LXD 600 and LXD 700 equatorial mounts include 8 ball bearings (4 on each axis!) and worm gear controls on both axes.

Meade Model 102ED: 4" f/9 ED Apochromatic Refractor. Shown with optional #1664 Electronic Drive System.

4" and 5" models include the LXD 600 Equatorial Mount and standard field tripod.

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Optional #1697 Computer Drive System has 4 drive speeds on both axes: 2x, 32x, 2° and 8° per second.

Press the keypad controller buttons of the #1697 Drive to move the telescope across the sky electronically. Enter any one of 747 standard objects (or one of 8000 optionally available library objects), press GO TO and the telescope slews directly to the object.

Enter in the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8° per sec.

Optional #1664 Electronic Drive System has 2 drive speeds on both axes: 2x, 32x.

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OBSERVER REPORTS: *ED* APOCHROMATIC REFRACTORS

Never in the 20-year history of Meade Instruments has a new telescope series been so thoroughly tested—and received such acclaim—by some of the world's most demanding and discriminating astronomers. A sampling of the reports we have received on Meade ED Apochromats:

"As an apochromat **and** *Schmidt-Cassegrain enthusiast of 22 years standing, I have been more than a bit anxious to get my hands on the new Meade APO's and LX200 SCT's. I think it is paramount that a "mainstream" company has gotten involved in the development of apochromatic refractors, so the average person does not have to pay a fortune and wait almost a year to get a quality, high-performance refractor. With some friends, I recently put the Meade 4" 102ED and 10" LX200* [See the Meade LX200 ad of this issue] *through extensive testing. The 4" was virtually perfect. The mount was very solid and the computer drive made finding objects in light-polluted North York very easy. The fast electric slew feature was much appreciated because it eliminated the need ever to loosen the RA and Dec locks. Set-up and orientation of the scope were easy as well. The optics: all I can say is "superb." We looked at Saturn, Epsilon Lyrae, M13, and other Messier objects, and all were excellent. I could not believe the colour correction I was seeing: I detected no on-axis colour whatever. We took the scope up to 360X and the image did not degrade at all. Saturn was very detailed and the contrast of the equatorial band on the planet and the variation in the planetary colours was amazing for a 4" refractor. The double-double was like four "bullet holes" and showed not a hint of the astigmatism or overcorrection I have seen in so many other APO's claiming to be "state-of-the-art." The Meade 102ED is a remarkable scope. Any scope that can support almost 100X per inch is a first rate instrument—I have seen too many other APO's fall apart at 50X and even 30X per inch."*—**Richard Anderson, Mississauga, Ontario, Canada**

"Further to my letter regarding your 4" APO, I thought you might like to hear the results of tests on your 5" APO at the recent Canadian Starfest convention. Through the 5" Saturn was terrific. Aside from the usual things such as the Cassini division, I could see the olivine cap on top of the ball, as well as subtle detail in the main equatorial belt. What really struck me as amazing was the true-to-life colour rendition the APO provided. ***The colour correction of the Meade 5" is as perfect as I've ever seen in a refractor.*** *When I compared the Meade APO to a few* [competing brand of] *refractors, I was seriously wondering why anyone would pay the prices they charge—on all objects the Meade was as good or better. The diffraction disks of stars were more accurately rendered in the Meade than in the* [competing brand of] *6" APO at the site. I can wholeheartedly recommend the Meade 5" APO. In terms of comparison to other brands on the market, the Meade is superior."*—**Richard Anderson, Mississauga, Ontario, Canada**

"I've been an amateur astronomer since 1959 and have observed through all manner of telescopes large and small, up to 40" aperture. I am writing to tell you that images through the Meade 6" ED/APO are absolutely stunning even by professional standards. Image contrast and definition are amazing. The quality and workmanship are flawless. Having joined the A.L.P.O. in 1965, I can only speculate on how much additional and useful observational work could have been accomplished, had quality apochromatic refractors such as this been available those many years. The image quality even to the edge of the field is outstanding, while the color correction and contrast are simply better than any telescope I've ever used."—**Orville H. Brettman, Past President, The Astronomical League, Huntley, IL**

"In this country where apochromatic refractors are used by almost half of all serious amateurs, the introduction of Meade American-made ED/APO refractors was frankly met with some skepticism. This skepticism has dissolved rapidly, however, as word has spread about these very fine instruments. My personal tests with the Meade 5" ED have proven that this lens is clearly the equal of the finest Japanese ED lenses. Images through the Meade 5" ED are of high contrast and I could see no false color even at high power. Diffraction rings are virtually perfect. Using the computer drive, the telescope centered objects automatically and greatly increased my observing efficiency. Thank you for giving Japanese amateurs a chance at reasonable cost to use high-performance, large-aperture ED refractors."

—**Tadashi Sudoh, Tokyo, Japan**

"Last night I used the new Meade 6" and 7" ED apochromatic refractors. These are, without a doubt, among the finest telescopes I've ever used. Period. The LXD 700 equatorial mount is truly a remarkable telescope mount. The computer control is no less than startling. After spending 3 minutes polar aligning the mount, I then entered the command to find Saturn. The motors of the huge 7-incher slewed directly to the planet and placed it exactly in the center of the field of the 4.7mm eyepiece. And the views: I have never seen such razor-sharp images of Saturn before. Both scopes gave exceptional images. Stars are like tiny pinpoints. I could go on and on, but suffice it to say, these telescopes are really astounding."—**Darrell Green, Burbank, CA**

"I just wanted you to know how thrilled I am with my new 4" 102ED refractor. My standards for precision optics are exceedingly high; I am an eye surgeon and routinely use an $80,000 state-of-the-art microscope to perform cataract surgery. I'm happy to say that every aspect of the scope lives up to my standards and expectations. The mount is extremely rigid with excellent vibration dampening characteristics. The #1697 computer drive performs flawlessly. Lastly, and most importantly, the optics are superb. Planetary and lunar contrast and detail are simply breathtaking. My sincere thanks for the obvious thought and dedication that your company put into this magnificent precision instrument."

—**Barry S. Seibel, M.D., Los Angeles, CA**

"I had my first look through the Meade 6" APO at the 1992 Astrofest Star Party. While the lines were long in anticipation, I finally feasted my eyes on Saturn and was literally knocked back by what I saw. Not only was Saturn huge in the 240X field, but almost three-dimensional as well. As I studied the image, I remembered the old saying "Good things are worth waiting for," and this telescope is worth every minute."

—**Vic Winter, Kansas City, MO**

"At a recent star party many apochromatic refractors were set up, including a 6" Meade ED/APO. All during the evening I walked back and forth among these telescopes, carefully comparing relative optical performance. After looking through several 6" [competing brand] *3-element APO's (both cemented and air-spaced designs), I noticed in all of these scopes that Saturn's minor ring divisions, Cassini division, and the ball of the planet were not of the same contrast brightness, but seemed to vary inconsistently. Some areas of the planet seemed "underexposed," while other areas with potential detail appeared subdued. I repeatedly went back to a 3-element 6" f/12* [competing brand] *planetary APO, but found that all of the 3-element APO's had the contrast problem. Amazingly, the Meade 6" f/9 ED air-spaced doublet APO produced a brighter image with increased sharpness, allowing features to be seen more clearly than through competitive triplets. "Brighter, clearer, sharper" is the way I would describe the Meade APO when compared directly to lenses of other designs."*—**Robert Petti, Lyndhurst, OH**

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☐ *All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

☐ The all-new **1992 Meade General Catalog—$3.00** postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

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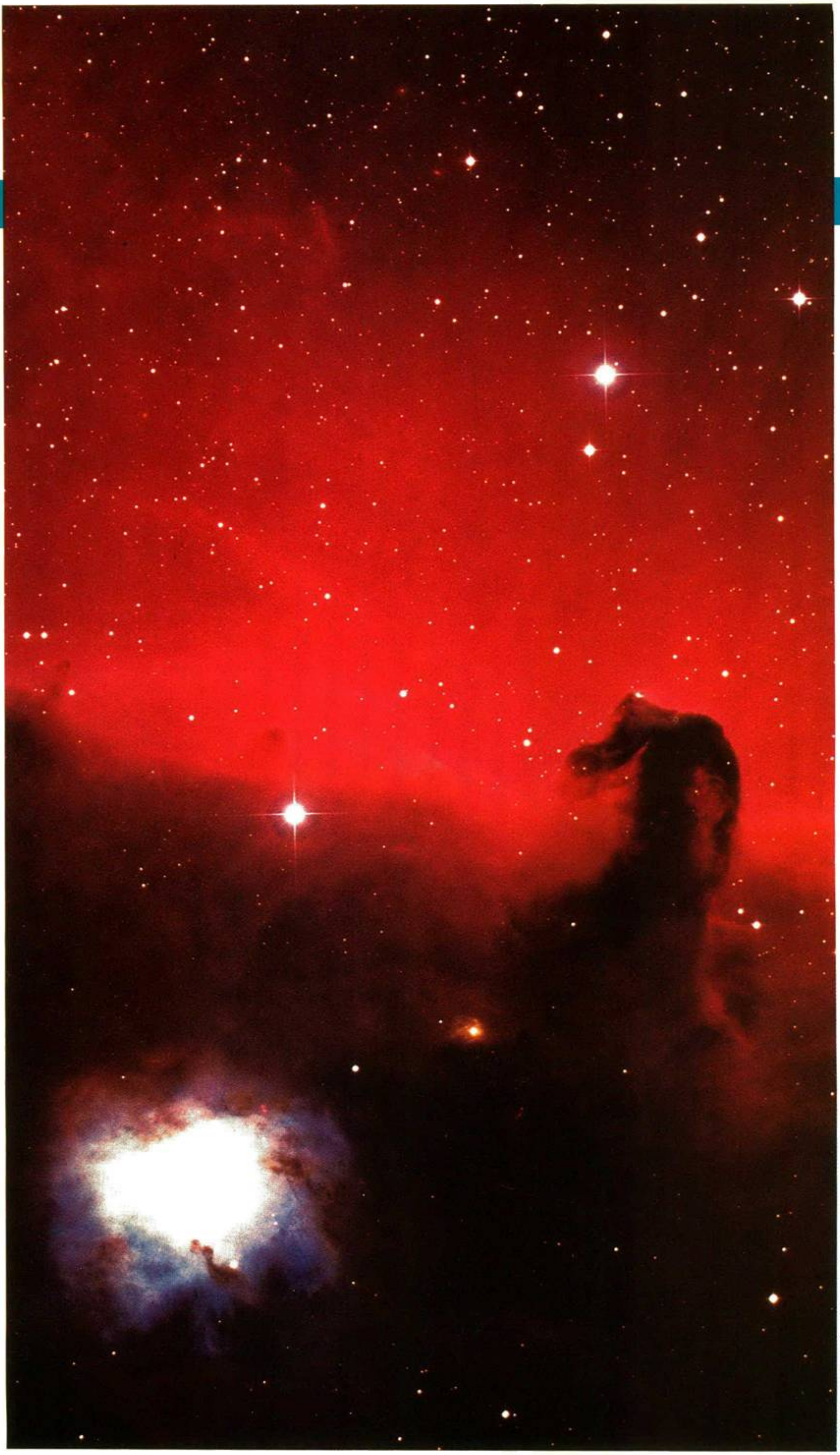
ON THE COVER: Two spiral galaxies collide, feeding a massive black hole with superheated gas that bursts forth in unimaginable brilliance — a quasar. Many astronomers now think that quasars arise in such collisions and mergers. For more details, see page 28. Illustration by Robert Eggleton.



CRIMSON TONGUES OF GAS glow softly behind a clump of opaque dust in the shape of a horse's head. The Horsehead Nebula in Orion is just one of the deep-sky sights you'll discover in our tour of the winter sky on page 78.

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20th ANNIVERSARY YEAR

ASTRONOMY

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The Audit Bureau

Behind the Scenes

WHEN ASTRONOMY GOT INTERESTING

Thirty years ago, astronomers stepped out of their well-trodden path and discovered that the universe was a lot stranger than they had been thinking. The crucial event was the realization that what we now call quasars were objects whose spectra showed larger redshifts than anything seen before.

The spectra rocked astronomy because they indicated that quasars were unlike any other objects known. The redshifts said that quasars were very distant, yet simple measurements showed that they were relatively bright. It was easy to see that great distance coupled with moderate brightness inevitably meant that quasars had to be extremely luminous intrinsically. And the implied luminosities demanded a mechanism to generate energy that was more powerful than anything astronomers knew of. What could possibly power these objects? No one could say.

The discovery of quasars was the first time in modern astronomy that observations had uncovered a major feature of the universe that left the theorists hopelessly guessing. Not by coincidence, I suspect, it was also the first time that a nonvisual technique — in this case, radio astronomy — had led the way to discovery. On page 28, Ken Croswell unfolds the story of the quasars and explains what astronomers now think these enigmatic objects are.

I like to think of the discovery of quasars as the moment when astronomy broke out of its rut and got interesting. It was the start of a period of discovery that continues unabated down to today. One trivial byproduct of this revolution in thinking is that terms like "quasar," "pulsar," and "black hole" have all become so familiar to everyone that Madison Avenue can sell us things with them! It's hard to realize that just a generation ago, these were things unknown or barely dreamt of — even by astronomers themselves.

Can such a pace be continued indefinitely? Hard to say. But another feature story this month — "How We'll Fix Hubble" (page 42) — deals with one means by which more discoveries will come pouring in. To the general public, the Hubble Space Telescope is an expensive failure, an inky blot on the national escutcheon. It's true that the telescope's primary mirror is faulty. But did you know that when Hubble's "glasses" arrive, it'll go from being merely 10 times better than Earth-based telescopes to about 100 times better? And people call this a national failure? There's little doubt that a repaired Hubble will still have less than its full abilities as designed. But the improvement will take Hubble a long way closer toward its original mission. And I'll be astonished if we don't see a "new" — and more interesting — cosmos in the outcome.

Sincerely,

Robert Burnham

Robert Burnham
Editor

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Letters

Comet Swift-Tuttle Recovered

How great it is that the parent comet of the Perseid meteor shower has been recovered after 130 years (AstroNews, December 1992). It's a relief to know that observers weren't imagining the particularly active Perseid displays of the past few years. The news of an outburst in 1992 that came 2.5 hours earlier with respect to the previous year's maximum made it highly likely that the parent comet was in the neighborhood.

Now if we can just shake ourselves of the remote possibility that the comet will hit Earth during its next apparition in 2126. Comet Swift-Tuttle the great killer comet of all time? Say it isn't so! — *Paul Roggemans, Mechelen, Belgium*

Anyone who thinks that a comet like Swift-Tuttle or another solar system body isn't capable of hitting Earth should recall the morning of October 18, 1992, when a brilliant fireball was observed by thousands across the East Coast. Poor Michelle Knapp, an 18-year-old high school senior living in Peekskill, New York, woke up that evening after hearing a loud crash outside. She reportedly said "The noise of it literally shook the windows." Her 1980 Chevy Malibu was demolished by the end result of the fireball, a 30-pound meteorite that was still warm to the touch minutes after striking the car. — *M.J. Wood, Sumner, Washington*

Where Have All the Plutos Gone?

Thanks for the thought-provoking article on Pluto-like planets by Alan Stern (September 1992). I don't quite understand two points, however — the mechanism that produced the Oort cloud and why Pluto has not suffered the same fate as its family. Do astronomers understand how these events occurred? — *Joop M. Houtkooper, Ouderkerk, The Netherlands*

— Pluto is protected by the gravitational force of Neptune, so it wasn't ejected like its fellow icy dwarf planets. Most of the ejected bodies left the solar system entirely, but some ended up in the Oort cloud that now surrounds the solar system.

Life on a Metal-Poor Earth

Neil Comins' article about a metal-poor Earth (October 1992) overlooked what might be an important scenario dependent on the lack of plate tectonics and thermal convection you would expect in a metal-poor Earth. Assuming Earth's water content would be the

[continued on page 12]

550 BC: Anaximander invents the star chart.

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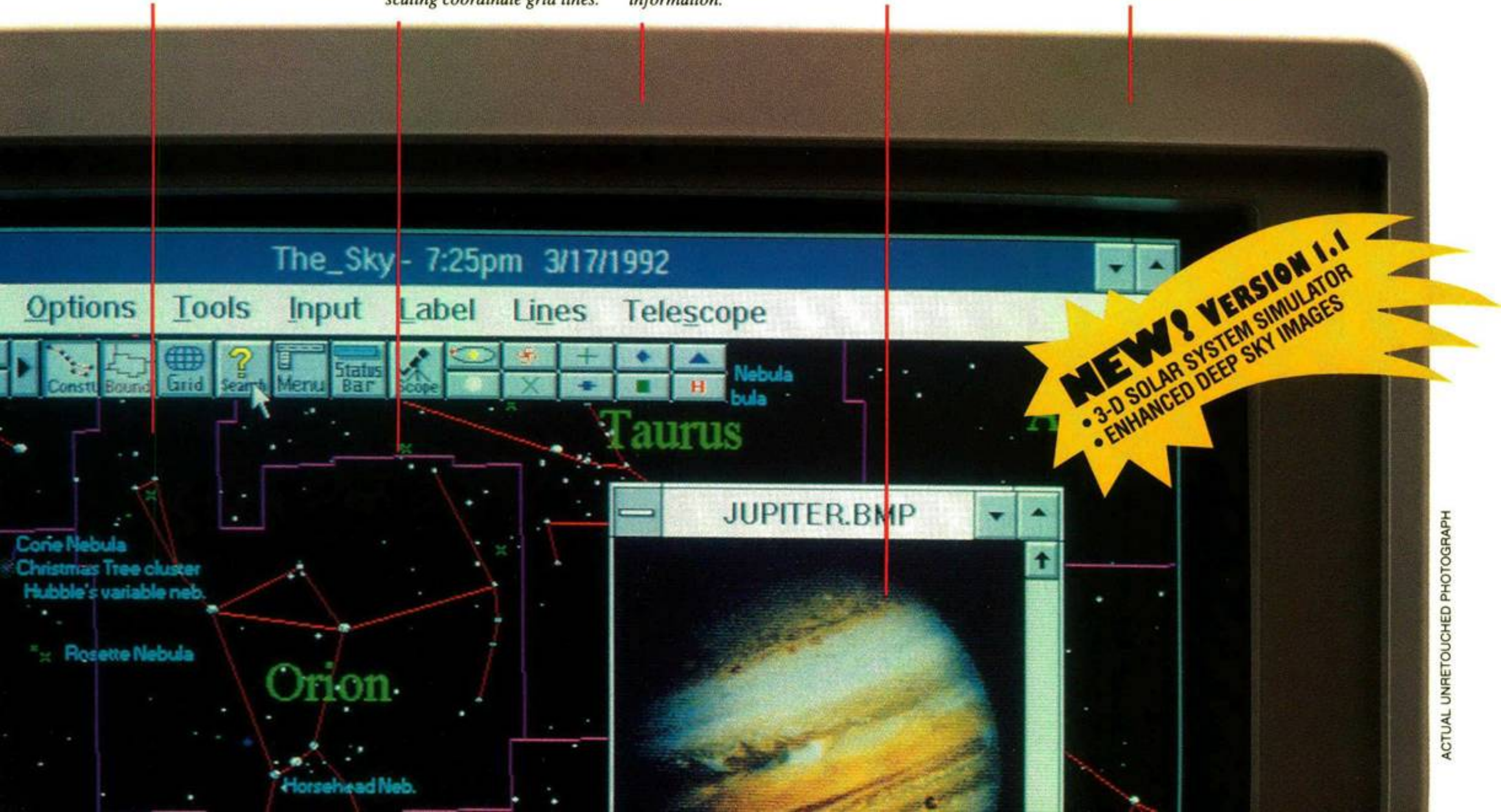
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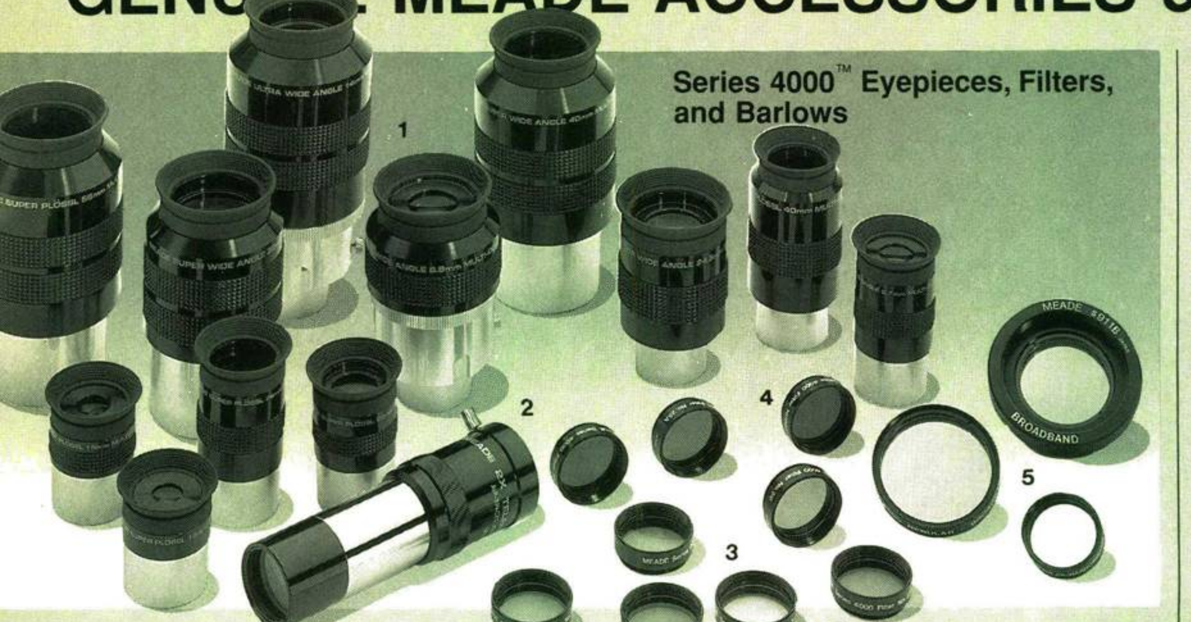

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1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

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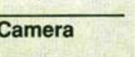
$74.95 (3.29)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$99.95** (3.29)

Camera Adapters (1.25" & .965")



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.
.965": $27.95 (2.79) **1.25": $29.95** (2.79)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.79)

Tele-Extenders

TELE-EXTENDER

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender:*(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$29.95** (2.79)

Variable Tele-Extender:

Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece. **$39.95** (2.79)

T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera. **$26.95** (2.79)

2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (3.29)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25" **$59.95** (3.29)

Orthoscopic Eyepieces (1.25")

Fine 4-element oculars that yield excellent image quality with any telescope. Computer-optimized design provides wide, flat fields, highly corrected for spherical and chromatic aberrations. Parfocal, multi-coated, 1.25" barrels. Threaded for filters. **Focal Lengths: OR 4, 6, 9, 12.5, 25mm.**
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The finest focusers in the industry. Meade rack and pinion mechanisms have precise, ultra-smooth action along the entire travel distance. Housings are machined for tight fit of the moving sleeve. All focuser models may be used on tubes of from 4" to 20" diameter; all accept 1.25" eyepieces. Mounting hardware included.

#71—The finest economical focuser available. Travel distance: 2.2" A precision mechanism, beautifully finished. **$44.95** (2.79)

#67—Includes spring-loaded gearbox for variable tension adjustment. Travel distance: 2.2". **59.95** (2.79)

Rack-and-Pinion Focusers (2")

#680--The most popular 2" focuser ever manufactured. Thousands in use. Spring-loaded gearbox; 3" travel. Includes 1.25" and 2" eyepiece-holders. **99.95**(3.78)

#682—Low-profile 2" focuser; body height only 1.75". Spring-loaded gearbox. Travel: 2.5". Includes 1.25" adapter. **99.95** (3.78)

Viewfinders: 30mm, 50mm, 60mm

#637: 6 x 30mm–Fine, 7° wide-field finder; coated, achromatic lens; crosshair eyepiece, 2-ring bracket with alignment screws. Attaches to tube diameters 6" to 12" **$49.95** (3.29)

#545: 8 x 50mm–*(lower photo)* Wide 5° field; coated achromatic objective; crosshair eyepiece. White tube. Ideal for telescopes of any aperture. See bracket below.
69.95 (4.28)

#544: 8 x 50mm–Same as #545, but in Meade blue. **69.95** (4.28)

#957: 9 x 60mm–*(top photo)* Collects 44% more light than 50mm; superior for faint objects; bracket below. **99.95** (4.68)

Bracket for 8 x 50mm: Fits Meade and Celestron SCT's, and other tubes from 7" to 20" diameter. **17.95** (2.79)

Bracket for 9 x 60mm: Fits tubes from 7" to 20" diameter. Removable dovetail included. **22.95** (2.79)

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Superb, fully multi-coated 11 x 80mm and 20 x 80mm Giant Binoculars, ideal for wide-field deep-space observing. **Rubber-coated bodies for rugged field use!** BAK-4 prisms yield bright, sharp, high-contrast images. Hard carry case, tripod adapter included.

11x80: $399.95(7.27)
20x80: $419.95(7.27)

45° Erect-Image Diagonal Prisms

Originally developed by Meade Instruments, these convenient diagonals erect the astronomical image, for terrestrial use of astronomical telescopes. Fully coated.

#927: for .965" focusers.
#928: for 1.25" focusers.
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Specify model desired. each **$49.95** (2.79)

HOW TO ORDER

- Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA
Orders: 800-843-4780; Info: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828. Info: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576. Info: 510-447-9570.

SCOPE CITY/Mail-Order, Simi Valley, CA.
Orders: 800-235-3344; Info/CA:805-522-6701

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Info/IL: 312-332-2000.

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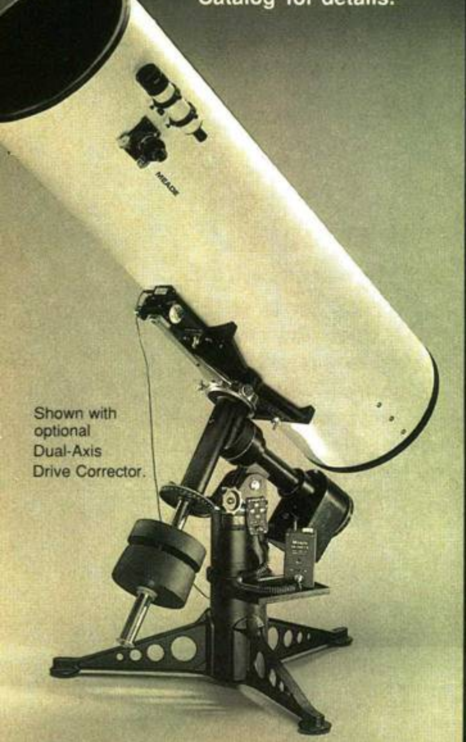

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■ **Accessories and Components:** Meade Starfinder telescopes include high-performance components throughout: **#71 Rack-and-Pinion Focuser** (1.25") for smooth, backlash-free focusing of the image; a coated achromatic **#637 6 x 30mm Viewfinder** with crosshair eyepiece and 7° field, for quick object-locating; **coated MA 25mm** (1.25") eyepiece; strong, durable spiral-wound **optical tube** with attractive white finish; and **cast aluminum mirror cell** for accurate mounting and alignment of the primary mirror.

■ **Optional Accessories:** See the opposite page for some of the many optional accessories available. Additional systems, including the **#55 Manual Declination Control**, **#43 Drive Corrector** and **#47M Dual-Axis Drive Corrector,** are described in the **Meade General Catalog.**

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■ **The 1992 Meade General Catalog— $3.00 postpaid— is available from any authorized Meade dealer or directly from Meade Instruments.**

■ **For further information call Meade Instruments toll-free at 1-800-854-7485 (in Calif. 714-556-2291) or contact one of these authorized mail-order dealers:**

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Orders: 800-422-7876; Info.: 405-364-0858.

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ADVANCED PRODUCTS DIVISION **Meade Instruments Corporation**

OBSERVER REPORTS: *LX200* SCHMIDT-CASSEGRAINS

"...After hours and hours of using this instrument, it is clear the quantum leaps that Meade has made in telescope technology...Planetary contrast and detail were simply unlike any 8" SC telescope that I had ever tested before...The more people looked, the faster word spread that something truly extraordinary was going on..."

"Last weekend I arrived at our club's dark sky site and set up next to a brand-new 8" LX200 owned by Mark, one of our club members. This was going to be a fun evening. Mark punched in a request for M57, the Ring Nebula. Less than 10 seconds later there it was, exactly in the center of the eyepiece! Very sharp image too. Next we tried a long slew, off to M31, the Andromeda Galaxy. Took about 15 seconds and there was the core of M31, again centered in the eyepiece. We punched in a request for Saturn. The scope buzzed over and centered the beautiful ringed planet (this could make a finderscope obsolete!). We ran the power up on Saturn. The LX200 gave a splendid view. Sharp image, lots of contrast. Refractor-like. The optics on this scope were outstanding, and the combination of ease of use and superb optics was impressive. This scope had better contrast and much sharper optics than I've seen on other SC's. One of the club members went inside to call his wife and let her know he was buying one. Congratulations! This is a very desirable scope you've created."—**Bob Beckley, Bedford, MA**

"I have made my best purchase of a lifetime. I saved for two years to have a superior telescope of my dreams and you have made them come true with the 10" LX200. The optical quality one must see to believe. I was actually able to see hints of dust lanes in M31 and spiral structure in M82; my greatest thrills were a confirmed sighting of Pluto and the resolution of M13 into individual stars. I have been in amateur astronomy for 23 years and I have never used such an incredible telescope."—**Michael D. Cloutier, Fair Haven, MI**

"While vacationing over the past week, I've had a chance to put the 8" LX200 through its paces. You've gone beyond the future and into sci-fi with this telescope. I want you to know that the LX200 has exceeded all my expectations, even better than my fondest dreams for a telescope of the future. Congratulations!"—**Roger Ressmeyer, Sag Harbor, NY**

"Because Schmidt-Cassegrain quality has been a personal crusade on my part, I was champing at the bit to test the new Meade 10" LX200. I have always believed that building an excellent Schmidt was within the realm of possibility, and the new LX200 is a real winner. The optics are so good I am now having trouble understanding how you can produce them to the level you have and sell them so inexpensively. I have been "educated" by "optical experts" who said it can't be done. I now have proof that it is possible. Because I know a Schmidt's optics are complex, I always test them with a Ronchi eyepiece as well as real objects. The Ronchi tells if the surface curves are ***accurate*** *and if the surfaces are* ***smooth.*** *Lack of smoothness will kill planetary detail by diffusing light into a hazy cloud around the planet. When I put the Ronchi on the Meade LX200 I couldn't believe what I saw! The bands produced by the Ronchi pattern indicated a surface as smooth as* ***any*** *refractor I have ever seen!! This level of smoothness is incredible in any reflective optical system. The Ronchi bands were also ruler-straight, indicating that the curves on the optics were right-on. No over- or undercorrection. Saturn was magnificent! The planet displayed more contrast and better colour rendition than any Schmidt I have ever owned—and I've owned 8 of them! The equatorial belt was markedly reddish-brown; the Cassini division was darker than I've ever seen it and I could easily see the Crepe ring thanks to the scope's high contrast. Views of deep-sky objects were excellent: M27, M57, and M13 all looked great despite light pollution at the site. The computer drive performed well. I quickly jumped from object to object and turned what was going to be a quick half-hour test into a very enjoyable* ***four-hour*** *observing session. There will be no trade-in of this instrument down the road, because you don't trade in perfection."*—**Richard Anderson, Mississauga, Ontario, Canada**

"At a star party in Austria last weekend I used an 8" LX200 for testing and observations. After hours and hours of using this instrument, it is clear the quantum leaps that Meade has made in telescope technology. Views of Saturn were startling! Planetary contrast and detail were simply unlike any 8" SC telescope that I had ever tested before! Stars were crisp and sharp. The more people looked, the faster word spread that something truly extraordinary was going on: Now people came with their testing tools and a Ronchi-grating confirmed the overwhelming impressions that everyone had during those observations. All lines were absolutely straight. Once the LX200's computer started to let the servomotors hum, the telescope attracted everyone on the observing grounds. I was scanning the heavens and soon people were standing in line to see NGC and Messier objects in rapid succession. Common exclamations were that here was a truly quality telescope that was a joy to use."—**Stefan Thiele, Wiesbaden, Germany**

"The key word to describe my 10" LX200 is versatile. *The LX200 is as simple or as sophisticated as my needs dictate. For casual observing I can quickly and accurately move from object to object. The superb optics and smoothness of the mounting make centering objects a visually exciting endeavor, not a fight. When I'm ready to use the technical sophistication of the LX200, the keypad handbox makes finding objects a matter of pushing a couple of buttons. I find that the LX200 makes technology work with me. I also have to mention the excellent support I have received from Meade. Any time I have called with a technical question, I have talked with a "live" person who is not only eager to answer my question but truly concerned with whether or not I am enjoying my scope. I find Meade's approach to business to be truly refreshing."*—**Steven L. Renshaw, Fresno, CA**

"I've owned 3 Schmidt-Cassegrains and a 12.5" Newtonian over the years, and recently at our club observatory, I used the most sophisticated commercially-available telescope I've ever seen, the Meade 10" LX200. I was impressed by the sharpness and contrast levels of the LX200. In light-polluted areas of New Jersey the use of a nebular filter is often required to enhance the contrast of deep-space objects, but when I saw the Crab Nebula (M1) clearly through the 10" LX200 ***without*** *a filter, I knew that the optics of the LX200 were obviously of the highest quality. As a result of this experience, I have ordered a Meade 10" LX200 for myself!"*—**John W. H. Simpson, Princeton, NJ**

"As an 8" LX200 owner, I am writing to tell you that I really love the instrument. In side-by-side testing against a friend's [competing brand of] *8" SCT, to say the least there was no comparison. My Meade LX200 was light-years ahead in optical quality and technical capabilities. The LX200 is clearly the best Schmidt-Cassegrain in the world. Period."*—**Jinder Virdee, St. Thomas, Ontario, Canada**

"I recently purchased the Meade 10" LX200 and have been enjoying the scope immensely. You have produced a very high quality product and it has lived up to all my expectations and beyond. The LX200 makes astrophotography a pleasure. The telescope's Smart Drive did a great job of assisting me in the 20-minute photo of M22, enclosed; it took very little effort as the telescope did basically all the work. You can bet I will highly recommend the LX200 to any amateur astronomer looking for a superb telescope."—**Alfredo Garcia, Las Vegas, NV**

"Having just returned from two evenings of viewing on Mt. Pinos, I felt compelled to write you about my experience, as this was my first chance to really take my new 10" LX200 through its paces. What a wonderful combination of superb optics, rigid mounting, and accurate electronics!! I can't remember ever having spent a more enjoyable or productive evening observing! I emphasize 'observing' because that's what the LX200 allowed me to do. Having the telescope slew to my requested objects allowed me to enjoy viewing more objects than I ever thought possible. And speaking of viewing, what great optics! Amazing contrast, pinpoint star images. I have never seen as much detail in the cloud bands of Jupiter. I can't say enough about this scope. It was a breeze to set up (I was aligned, tracking, and observing in 5 minutes). The mounting is VERY solid. This telescope has an amazing array of features, outstanding optics and mounting. You've produced an outstanding product."—**Charles Kuhn, Culver City, CA**

Shouldn't you be using the most advanced Schmidt-Cassegrain ever manufactured? Meade 8" and 10" LX200's are available for prompt shipment. Call or write your authorized Meade dealer today for full details.

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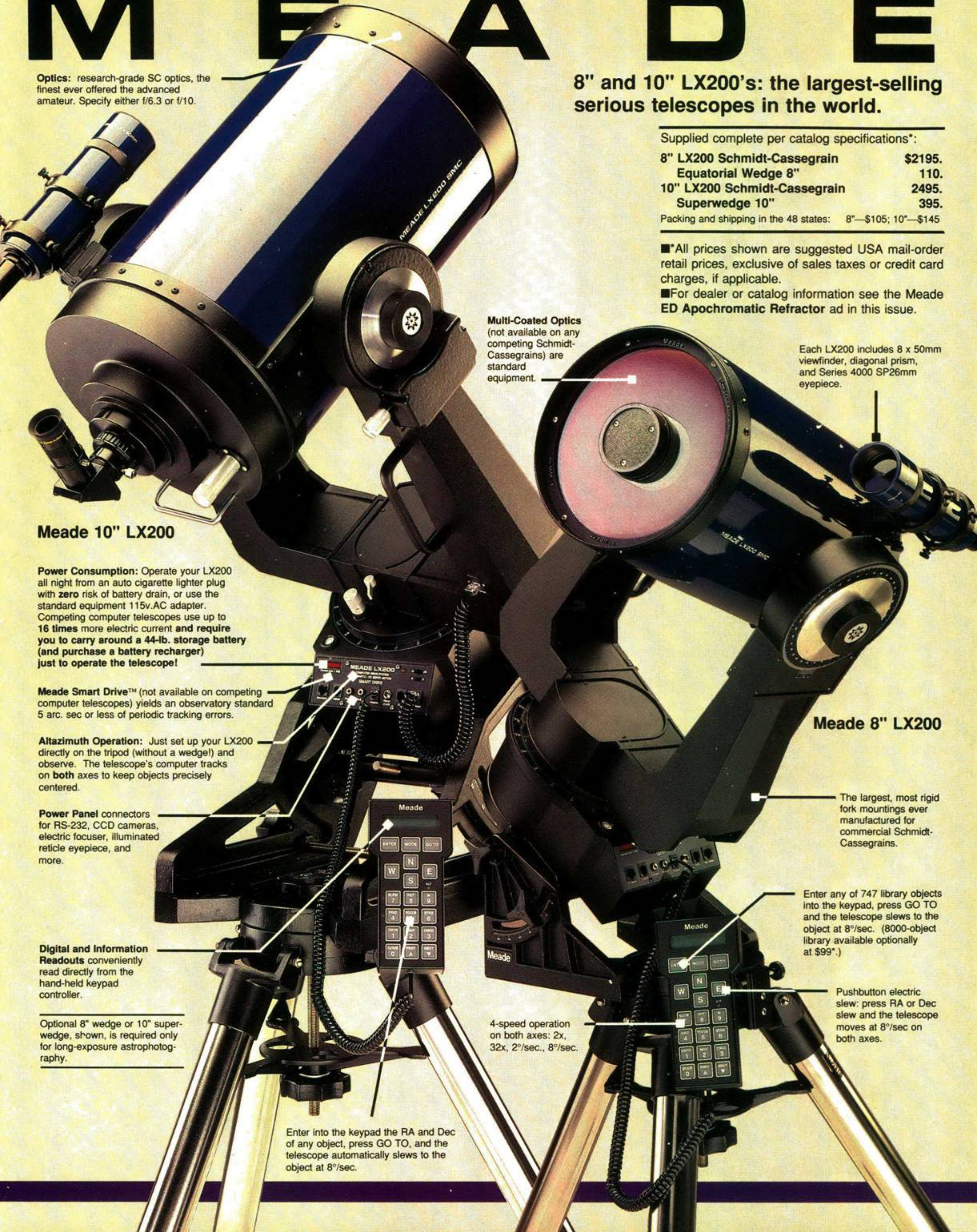
■For dealer or catalog information see the Meade **ED Apochromatic Refractor** ad in this issue.



Optics: research-grade SC optics, the finest ever offered the advanced amateur. Specify either f/6.3 or f/10.

Multi-Coated Optics (not available on any competing Schmidt-Cassegrains) are standard equipment.

Each LX200 includes 8 x 50mm viewfinder, diagonal prism, and Series 4000 SP26mm eyepiece.

Meade 10" LX200

Power Consumption: Operate your LX200 all night from an auto cigarette lighter plug with **zero** risk of battery drain, or use the standard equipment 115v.AC adapter. Competing computer telescopes use up to **16 times** more electric current **and require you to carry around a 44-lb. storage battery (and purchase a battery recharger) just to operate the telescope!**

Meade Smart Drive™ (not available on competing computer telescopes) yields an observatory standard 5 arc. sec or less of periodic tracking errors.

Altazimuth Operation: Just set up your LX200 directly on the tripod (without a wedge!) and observe. The telescope's computer tracks on **both** axes to keep objects precisely centered.

Power Panel connectors for RS-232, CCD cameras, electric focuser, illuminated reticle eyepiece, and more.

Digital and Information Readouts conveniently read directly from the hand-held keypad controller.

Optional 8" wedge or 10" super-wedge, shown, is required only for long-exposure astrophotography.

Meade 8" LX200

The largest, most rigid fork mountings ever manufactured for commercial Schmidt-Cassegrains.

Enter any of 747 library objects into the keypad, press GO TO and the telescope slews to the object at 8°/sec. (8000-object library available optionally at $99*.)

Pushbutton electric slew: press RA or Dec slew and the telescope moves at 8°/sec on both axes.

4-speed operation on both axes: 2x, 32x, 2°/sec., 8°/sec.

Enter into the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8°/sec.

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same, any land masses would eventually be weathered below sea level. Without tectonic mountain building or convective plumes to replenish the surface, the planet would become one large ocean.

Wouldn't this be more important than some of the other effects Comins mentioned? — *W. Calvin Morris, Venedocia, Ohio*

— Although plate tectonics may not occur on a metal-poor Earth, volcanism may, depending on the amount of heat generated by the decay of radioactive elements in the mantle. If the amount of radioactive elements were insufficient to drive volcanism, then erosion would eventually reduce the continents to near sea level. The continental shelves might be so large that the continents would not erode to below sea level, so some landforms would still exist.

Scoping Out the Helix

I look forward to every article in ASTRONOMY, especially the "Backyard Astronomer." In the September 1992 issue your observing article titled "Hunting down the Helix" by Phil Harrington was well written, but Harrington's description of how to find the Helix (NGC 7293) seems overly complicated. I find the object by drawing an imaginary line from Fomalhaut to Delta Capricorni. Midway between these stars, and with the scope nudged a touch northeast, lies the object. The Helix appears as a small gray cloud in my 13.1-inch scope. When I use a UHC filter the view rivals an observatory photograph. Contrary to Harrington's statement, the Helix is a piece of cake to find. — *K. Pariagh, Sangre Grande, Trinidad and Tobago*

Phil Harrington's article mentioned the asterism formed by 41, 47, Nu, 66, and 68 Aquarii, which serve as a guide to finding the Helix. Harrington refers to this asterism as the "bow tie." No doubt some readers are familiar with the "baby scorpion" formed by 103, 104, 105, 106, 107, and 108 Aquarii, which lies about 10° east of the bowtie. (See *Deep Sky*, Spring 1989.) The stars of Harrington's bow tie form a remarkable mirror image of this little asterism. — *Miles Paul, Victoria, British Columbia, Canada*

How Good are Big Binox?

I enjoyed your guide to buying binoculars (November 1992). The information was helpful in determining what sizes, types, and brands to investigate when making a serious purchase.

I must disagree with your assessment of 20x80 binoculars, however, which seems rather negative. I find a pair of 20x80s an excellent choice for observing the Moon, planets, comets, and deep-sky objects. They show a greater amount of detail than lower power binoculars and offer a darker field of view, which results in higher contrast images of bright objects. My 20x80s show many objects better than my 4-inch telescope does. — *Peter A. Rasmussen, Heber Springs, Arkansas*

— Any binocular, big or small, can be used for astronomy. We felt that recommending high-power binoculars only compounds the misconception many people starting out in the hobby have about the constant need for high magnification in order to see anything. As Mr. Rasmussen points out, in the hands of a knowledgeable user, 20x binoculars can provide superb views of selected targets. But for most viewing we recommend that observers start out with a lower power model.

Variable Star in the Ring Nebula?

A group of deep-sky observers in Sweden feels that we have identified a star within the Ring Nebula (M57) in Lyra that appears to have brightened slightly since August 1992. We think this star may be a variable. For more information, please write to me. — *Riku Henriksson, Nauli, 37910 Kylmakoski, Finland*

Corrections

In "Eye on the Sky" (October 1992) Deborah Byrd stated on page 48 that the Orionid meteors smash into Earth's atmosphere at 42 miles per hour. The sentence should have read 42 miles per *second.*

The supplement *Buying Binoculars for Astronomy* included with the November 1992 issue incorrectly listed the Orion Telescope Center's 14x100 Supergiant binoculars as having BK-7 prisms and standard coatings. These models in fact feature the better quality Bak-4 prisms and full multicoatings on all optical surfaces. ☐

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, *P.O. Box 1612, Waukesha, WI 53187-1612. Letters may be edited for length and clarity.*

HOME IS WHERE YOUR OBSERVATORY LANDS

by Don Parker

Living through Hurricane Andrew's relentless sweep through Florida last August was an experience I won't forget. I can assure you that the scenes of devastation you saw on TV did not even come close to what it was really like, at least where I live in Coral Gables. Houses, streets, and familiar landmarks simply vanished, replaced by uprooted trees and piles of rubble. The landscape took on a surreal appearance — trees left standing but stripped of their leaves, telephone poles snapped like match sticks, road signs twisted like pretzels, and yachts protruded from bedroom windows. Salvador Dali would have loved it. The oppressive heat and ever-present stench from rotting fish and vegetation merely added to the unpleasant scene. And the threat of looters and the inability to communicate with friends and relatives completed a picture of near-total physical destruction and psychological trauma.

But there was a brighter side. Contrary to the picture of helplessness portrayed in much of the national media, most people began to rebuild immediately, or at least to make do. Dark humor sprang up all over, even in the most devastated areas. Most of us had to paint our names and those of our insurance companies on our houses because the insurance adjusters couldn't locate us by street signs and house numbers — these had disappeared. "House graffiti" soon followed. Beside the countless variations on "You Loot, We Shoot," there were "Road Kill Cafe, Open 24 Hours," "Motel Hell — Vacancy," and my favorite, "Home Is Where Your Roof Lands." Trucks from Georgia Power and Light (to which we owe many thanks) sported "We Do Andrew" signs.

All of this led to a drastic restructuring of priorities. Before Hurricane Andrew, my main priorities were

- try to wake up early enough to observe Mars; pray for good seeing.
- convince my wife that a faster computer is essential to family's bliss and well-being.
- fix TV remote control (humankind's most significant invention).
- call Jack Newton and hope to convince him to lend me his CCD camera.

After Hurricane Andrew, my priorities looked more like this

- find something to drink.
- get ice for above drink.
- keep swimming pool full. The pool is not for recreational purposes but rather provides a source of water to pour into toilets. In most families the Flushing of the Toilet became an event that approached religious significance. When the proper number of water buckets was applied to the toilet, the Event occurred and family members danced with glee in a ceremony reminiscent of ancient Druidic festivals.
- get rusty chain saw operational. The "Sounds of Andrew" was a discordant symphony of chain saws and electric generators.
- try to buy a generator for less than the cost of the Chrysler Building.
- hook up above generator to house without causing lights to dim and computers to falter in Cleveland.
- find plywood, tar paper, and roofing nails. If unable to obtain these materials, marry off daughters to roofers.

There were other priorities, of course, like doing laundry and bathing (this rose to #1 after about a week). Note that astronomy is nowhere on the list. Fortunately for my sanity, this changed a few days after the storm.

During the five-day period A.A. (After Andrew) and B.G. (Before Generator), my family and many of our neighbors slept outside. Our houses were simply too hot, too wet, and too smelly to permit sleep. In addition, sleeping outside allowed us to watch for looters, who were a very real problem immediately after the storm. Like the wagon train pioneers of old, we slept with our trusty .44s by our sides. This not only discouraged looters but also prevented the roofers we had captured from escaping.

I will never forget the first night, when I looked up at the stars and suddenly realized that what I thought was a cloud heralding rain was actually the Milky Way in Scutum! And it stretched on through Cygnus and even into Cassio-peia. Without the light pollution from Miami, our hard-hit neighbor to the north, I could plainly see Ursa Minor, Cepheus, and Draco and discern numerous rifts in the Milky Way.

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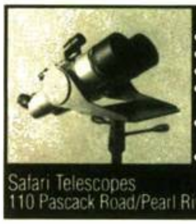

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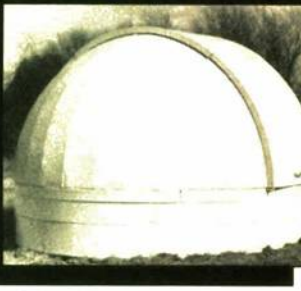

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The next night I went to "bed" armed with binoculars. Sure enough, the North America Nebula was a binocular object, just like at the Texas Star Party! Then some of our neighbors wandered over, asking the names of various stars. Luckily I'm not a very good pistol shot, so most of the neighbors survived the trip into our yard and got great views of the Milky Way through 7x50 and 11x80 binoculars.

By the third night we were hosting a neighborhood star party, using focused-beam halogen flashlights as pointers to outline the constellations and to direct binocular viewers to objects like the Lagoon Nebula. Many of these people had never looked up at the night sky before, but faced with no TV and forced to sleep outside in mostly supine positions, they couldn't help but notice the beauty of the starry nights. Though I don't expect many of these folks to get hooked on astronomy, they certainly took delight in what they saw. At the least, astronomy created, for a brief time anyway, a closeness among our neighbors.

Each night the dome of light pollution to the north increased as electric power was restored to the northern parts of Miami. Then our generators came. Color TV and electric lights and fans once again became part of our lives. We retreated back into our homes and forgot about those beautiful evenings under the stars. (Interestingly, our television's "first light" was a PBS program about the fragility of Earth.)

But what about "serious" astronomy? Mars was brightening in the morning sky and the Mars Section of the Association of Lunar and Planetary Observers (for which I am one of the recorders) had been asked to monitor the planet for pre-opposition dust storms. And I had no telescope! I had disassembled my 16-inch Newtonian before the storm, and luckily it suffered no damage. However, Andrew had relocated much of my observatory to a neighbor's yard, and it would be some time before I could rebuild. I was left with a narrow observatory deck that lies 15 feet above the ground. Add another 7 to 8 feet for the eyepiece height and this meant I would be perched on a stepladder over two stories up with no walls or guard rails. If someone of my weight fell from that distance, it could trigger another wave of mass extinctions.

Over and above these logistical problems loomed the fact that I seem to have painted myself into a corner. During the past two years, I have exclusively used a CCD camera to image the planets. Being an ecologically sensitive kind of guy, I had converted my photographic darkroom into a retirement home for Palmetto bugs (a Floridian euphemism for cockroaches the size of minivans). Over the past year or so, amateur astronomers have shown the value of using CCD technology to observe Mars, producing good images even when the planet's apparent diameter was under 5 arcseconds. But CCD astronomy requires computers and other electronic equipment, none of which particularly like the quality of electricity that a generator provides. Thus my chances of doing any patrol work on Mars before November seemed pretty remote.

Just when things looked hopeless, I had a flash of inspiration — I could actually look at the planet in the eyepiece and maybe even draw what I saw. Though I would no longer feel like a real astronomer, this might just work. One morning I set up my old homemade "standard" 6-inch f/8 Newtonian on the driveway and quickly rediscovered amateur astronomy. With magnifications of 50x to 60x per inch of aperture, I could readily discern surface features on the 7-arcsecond-diameter Martian disk. And the planet was a pretty sight to boot. I even dug out my old filter wheel and found that, contrary to what "experts" (like me) had written, even dense filters like the deep blue Wratten 47 could help reveal limb hazes and the bright North Polar Hood. Most important, however, was that this lowly telescope could be used to determine the presence or absence of dust storms on the Red Planet.

Since this first Mars observation, my little 6-inch has seen a lot of action. Neighbors have been thrilled by views of Saturn and the famous double double star, Epsilon Lyrae. They have been thrilled even more that they can observe these objects sitting on a stool rather than hanging off an 8-foot stepladder.

So even though Hurricane Andrew was a terrible disaster, some positive consequences came out of it. For many of us, the hurricane provided an opportunity to get back to basics with family and friends and even strangers. For me this carried over into astronomy as well. I'm sure that I will soon be imaging the planets again from a brightly lit, air-conditioned room with my back to

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the telescope, but I will always remember those balmy evenings spent really observing and having fun with the little reflector.

Now I wonder what my 6-inch scope would do with Jack Newton's CCD camera.

AN ASTRONOMER IN EVERY CHILD, A CHILD IN EVERY ASTRONOMER

by Mike Lynch

Do you remember your first look through a telescope? Mine came through a 3-inch reflector my dad and I bought for just $29.95 (that's right — just $29.95). The rugged lunar surface and Saturn's rings literally brought goosebumps to my skin. I was hooked on astronomy for life.

I remember spending many wonderful nights in my suburban Louisville yard, searching for the wonders of the universe. I couldn't believe I was seeing Messier objects with such a simple scope. And the spectacle of the 1966 Leonid meteor shower thrilled my 13-year-old eyes as no other astronomy event has, though Halley's Comet came close.

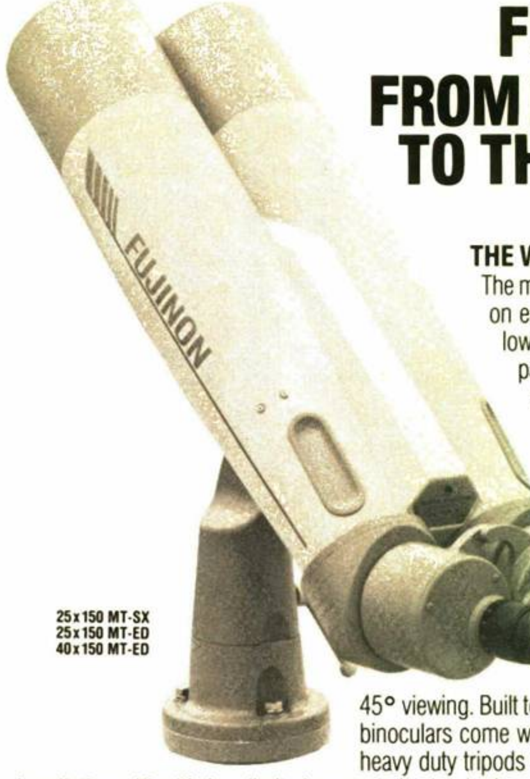
I sometimes wonder why it is so hard to recapture that sense of awe. After all, I have a much larger telescope now. Each month ASTRONOMY informs me about the same celestial objects I enjoyed as a boy. But it also brings more sobering stories — reports on light pollution, the fiscal constraints hindering astronomical exploration, and the increasing cost and complexity of instruments intended for amateurs.

When I read stories about people who have bought or built an amazing piece of equipment, I ask myself whether I actually share the same interest. After all, in comparison my modest equipment seems light-years behind the latest gadgets.

That's when I realize I've begun to lose the childhood sense of wonder that drew me to look at the sky in the first place — a sense that I had hoped I'd always keep.

Perhaps that's why I found talking to groups of children about the return of Halley's Comet so satisfying. Classes and scout troops were spellbound by information about the most famous comet, one they had heard so much

[continued on page 17]



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about and would soon see with their own eyes.

I learned early on the value of involving individual listeners. I still speak on astronomy to young audiences, and I usually begin by asking the question: "Do any of you have a hobby?" Nearly every hand shoots up, so I ask them to tell me about their hobbies. Astronomy, I then tell them, is my hobby, and I find it just as fun and interesting as they find theirs.

I try to explain astronomical concepts in ways they can understand easily and demonstrate ideas with simple examples. For instance, when I explain what happens when a meteor hits Earth's atmosphere, I ask the children to rub their hands together. At least one child usually can tell me that friction causes their hands to warm up. That same friction, I tell them, causes meteors to glow.

Their eyes begin to glow, too, when I tell them about some of the spectacular meteor showers I've witnessed. Their enthusiasm reminds me of how I began to warm to astronomy when I was their age. If I can just kindle in them the same sense of fascination, I think, they may also carry it with them through their lives.

In addition, I encourage kids to borrow their family's binoculars, ask their parents how to use them, and turn them to the sky. I purposely avoid talking about how big some telescopes are and how much they cost. Rather, I tell kids how much astronomy is available to them with no more than their eyes and binoculars.

In revealing the universe to a new generation, I'm rekindling my own interest, first sparked well before these children were even born. Make no mistake — I'd love to make a tangible contribution to the science of astronomy. But my limited pocketbook and the pressures of everyday life keep delaying that.

Even if I do make that contribution, I hope the sense of wonder I began this hobby with won't disappear. I hope I'll always find satisfaction in "catching a falling star" with the naked eye, scanning the Milky Way with binoculars, and shooting a wide-angle photo of the nighttime sky with a camera mounted on a handmade wooden contraption.

Just as I think there's an astronomer in every child I talk to, I think there's a child in every astronomer. I know there is in this one, at least. And I hope he never grows up. □

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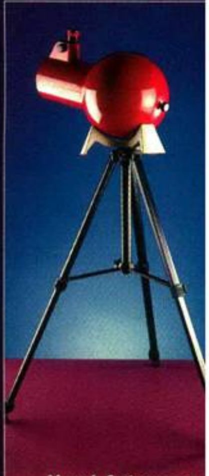

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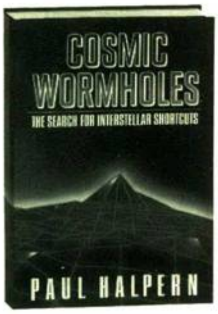
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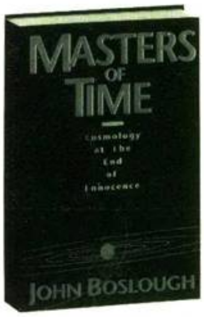
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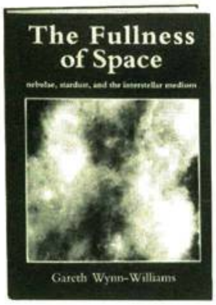
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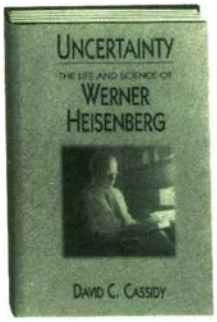
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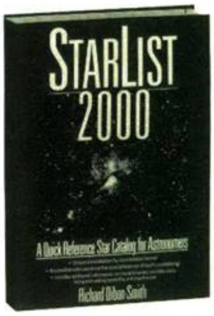
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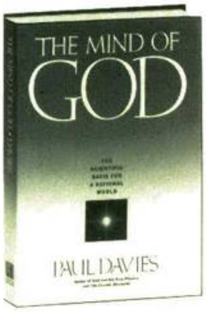
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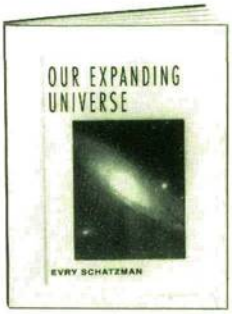
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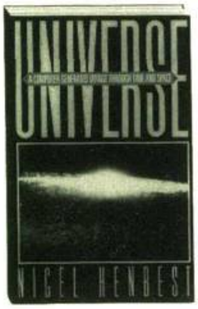
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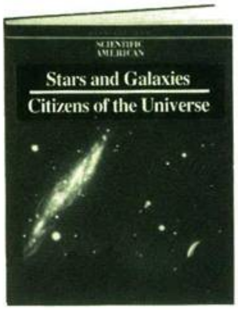
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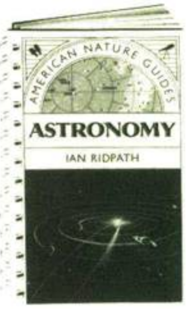
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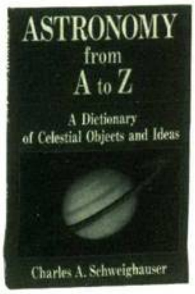
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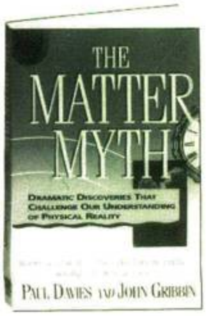
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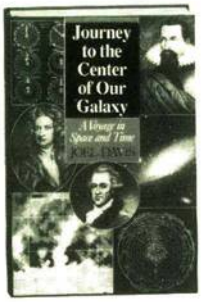
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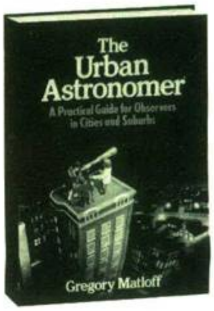
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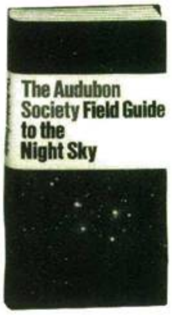
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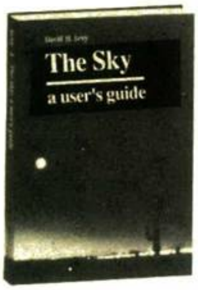
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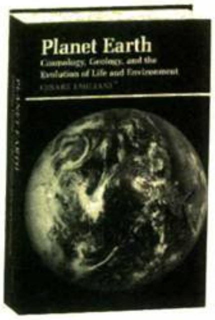
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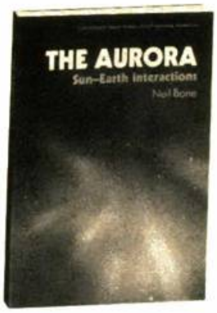
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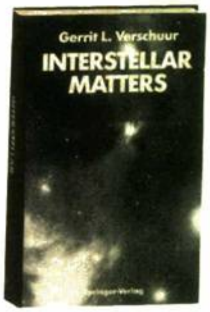
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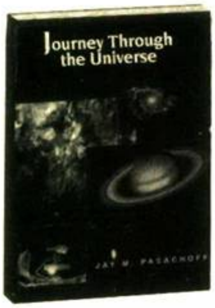
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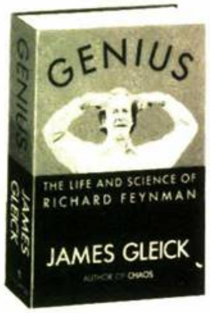
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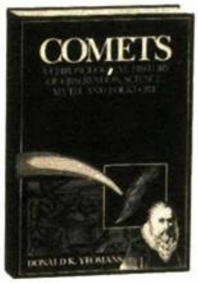
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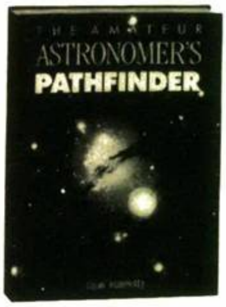
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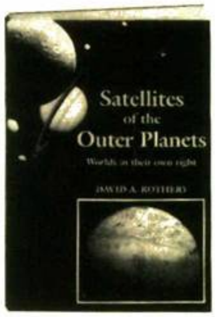
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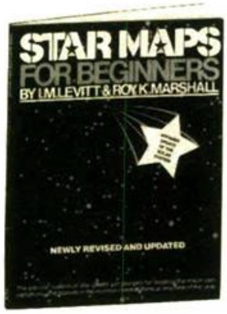
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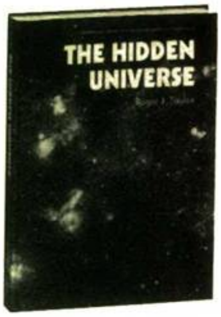
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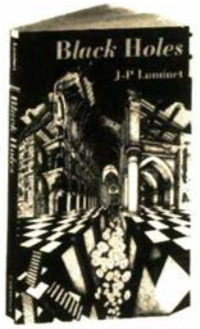
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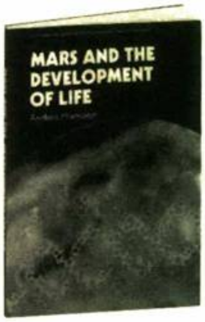
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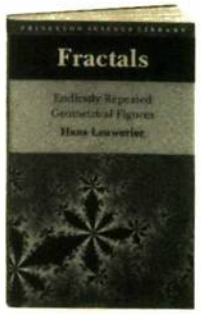
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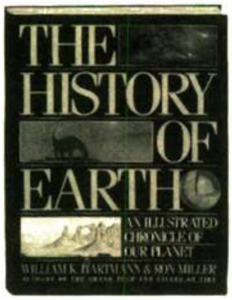
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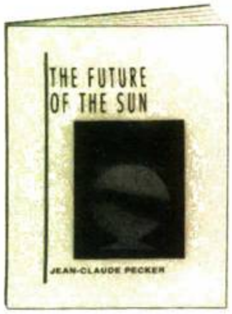
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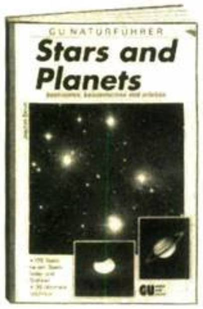
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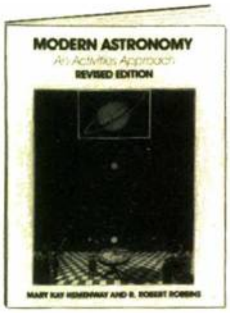
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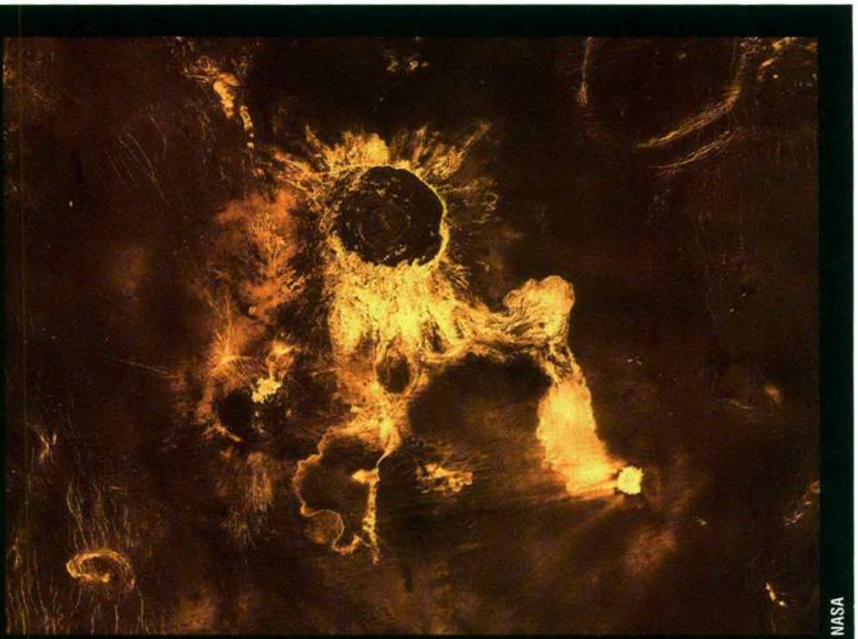
COMET OUTBURSTS EXPLAINED?

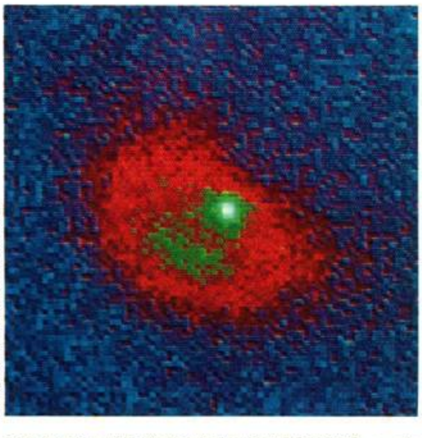
In late 1990 Comet Halley unexpectedly flared into activity despite the fact it was then halfway between the orbits of Saturn and Uranus. Astronomers at the University of Notre Dame and NASA's Goddard Space Flight Center have now identified a mechanism that could explain why comets such as Halley can brighten by as much as 10,000 times in a few hours.

Instead of warmth from the Sun causing the outburst, the astronomers suggest that heat from a chemical reaction vaporizes some of the comet's ice, producing a sudden release of gas and dust from the icy nucleus. Terrence Rettig, Stephen Tegleer, Dan Pasto, and Michael Mumma, writing in the October 10, 1992 issue of the *Astrophysical Journal*, point out that when individual hydrogen cyanide (HCN) molecules link together to create long molecular chains, lots of heat is released. HCN is a common constituent of comets and when linked into long chain molecules forms dark dust compounds. Comet surfaces are known to be very dark and may be coated with a dark crust of hydrogen cyanide dust.

According to Rettig, "Combining HCN molecules in a 20- to 100-meter-wide region on a cometary nucleus may be sufficient to raise the temperature of the ice to produce the dramatic outbursts seen by many observers. The energy released is enough to produce a brightening of up to 9 magnitudes and a mass loss of as much as a million tons." The trigger mechanism for the reaction can be any energy source — ultraviolet light, heat, solar protons, even cosmic rays coming from interstellar space. Just a few molecules combining is enough to set off a chain reaction and a sudden release of heat.


NASA

FLOWLIKE STRUCTURES SURROUND the second largest crater on Venus in this new image from the Magellan orbiter probe. The flows from 108-mile-wide crater Isabella may have formed when a stream of hot gases and melted and solid rock raced across the Venusian landscape after the impact event. A similar process occurs on Earth during violent volcanic explosions, such as the 1991 eruption of Mount Pinatubo. In the case of Isabella, however, the heat that generated the debris flow came from an impact, not from a volcanic explosion.


European Southern Observatory

SUDDEN BRIGHTENINGS OF COMETS, such as Halley seen here in February 1991 after an outburst, may be caused by chemical reactions on their dusty surfaces.

UNIVERSE APPEARS OPEN

One of the great unanswered questions about the universe is whether it is open, expanding forever, or closed, eventually collapsing upon itself. Neta Bahcall and Renyue Cen of Princeton University present a model of galaxy clustering in the October 20, 1992 issue of *Astrophysical Journal Letters* that suggests that the universe is open.

Astronomers describe the fate of the universe by comparing its density to the critical density, the cut-off point beyond which the universe would either collapse on itself or expand forever. If its density is less than the critical density, the universe is open because it has insufficient mass to stop the expansion. If its density is greater than the critical density, the universe is closed because its gravitational attraction will eventually pull all matter together. If its density is exactly equal to the critical density, it is a flat universe; it will neither expand forever nor ultimately collapse.

One traditional method of determining the density of the universe is to measure the density of galaxy clusters by means of the gravitational attraction of individual galaxies to the cluster. This technique suggests a density of 20 to 30 percent of the critical density. On the other hand, inflationary models of the universe require that the density be nearly equal to the critical density, or nearly five times higher than the technique using galaxy clusters.

Bahcall and Cen's model, however, produces results similar to observed galaxy clustering. Using over 15 million test particles to trace the motion of mass through the universe, Bahcall and Cen looked at how matter clustered in their computer model. They found that their model best reproduced observed clustering by galaxies only for low densities, around 25 percent of the critical density. Their result is consistent with several other observable cosmological quantities, such as the recent Cosmic Background Explorer (COBE) satellite's discovery of fluctuations in the microwave background radiation.

More importantly, they also found that models with a density near the critical density are inconsistent with clustering observations. They can construct flat universe models that agree with individual observations, but these models violate other constraints such as the COBE results or cluster frequency. However, don't discount inflationary models just yet; all of these models still depend on the nature of the unseen "dark" matter contained in galaxy clusters.

YOUR CAR WAS HIT BY WHAT?

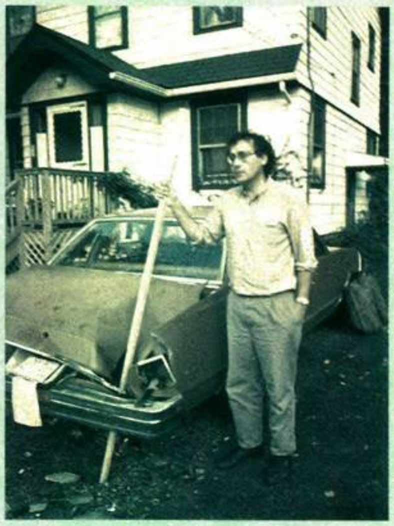
On the evening of October 9, 1992, a piece of rock from an asteroid collided with Earth. As it skimmed through the atmosphere traveling north up the East coast of the United States it created a fireworks show seen by millions. Much of the asteroid fragment burnt up in the fiery entry. But one piece managed to survive and strike the surface of Earth. After orbiting the Sun for several billion years, the first solid object this piece of asteroid hit was Michelle Knapp's 1980 Chevy Malibu sitting in a driveway in Peekskill, New York.

The 27-pound meteorite measures 11.5 by 6.5 by 4.5 inches. When it hit, it punched a hole through the trunk of the car and smashed into the ground below, gouging out a 3-inch deep crater.

The meteorite is an H-group chondrite. Chondrites are stony meteorites and make up about 86 percent of all observed falls. H-group meteorites are the second most common type of chondrites. They are made of silicon, magnesium, oxygen, and iron.

Reports in the news media at the time of the fall suggested the meteorite was part of the Draconid meteor shower (also known as the Giacobinids) that was in progress that weekend. This meteor shower originates from material cast off by Comet Giacobini-Zinner, raising the intriguing prospect that the Peekskill meteorite is a piece of a comet. However, the meteor traveled from south to north; the radiant of the Draconid shower was in the northern sky at the time. Meteors from the Draconids would have been coming from the north. This suggests the Peekskill fall had nothing to do with the Draconids but was purely coincidental.

The stony composition of the sample also suggests it is a piece of rocky asteroid, not an icy comet. However, researchers at the University of Western Ontario are examining videos of the meteor entry in an effort to trace back its original orbit around the Sun. In addition, fragments could be seen breaking off during the meteor's flight. It is possible other pieces made it to the surface, but so far there are no reports of other rocks falling from the sky on October 9. The rest of Peekskill's cars seemed to have survived unscathed.



Mark H. Anders/Lamont-Doherty Geological Observatory

THE PEEKSKILL METEORITE HIT at an angle of 77°, as shown by geophysicist Mark Anders, holding a stick placed through the Chevy that took the impact.

IS THE COMA CLUSTER STILL FORMING?

The Coma cluster of galaxies is nowhere near as old as astronomers once thought and may, in fact, still be forming. That's the startling conclusion drawn by a team of British researchers from recent X-ray observations of the cluster, which show that this vast collection of galaxies apparently consists of many smaller groups in the process of merging.

The Coma cluster is one of the closest galaxy clusters to Earth, lying about 300 million light-years away, and as such has been one of the most intensely studied. For a long time, astronomers thought that the cluster's galaxies were distributed smoothly over the entire cluster. Recently, however, a number of astronomers have claimed that many of the cluster's galaxies clump together.

Because such groups would merge with the rest of the cluster well before the universe reached its present age, their existence clearly implies that the cluster is still forming. But establishing the reality of the clumps based on optical observations alone is tricky — different researchers using different statistical tests reached different conclusions.

X-ray studies provide an alternate and in many ways a clearer view, zeroing in on hot gas in the cluster. The gas — either left over from when the galaxies formed or subsequently stripped from the galaxies — glows brightly in X rays because it is heated to temperatures up to a million degrees. And because the gas is held in place by gravity, it concentrates in regions of higher mass.

Using an X-ray telescope on board the 1985 Spacelab-2 mission, the British team has found that the gas also shows a blobby distribution. A "bridge" connects a smaller blob of X-ray emission to the main cluster, and the smaller blob coincides with one of the galaxy groups tentatively identified by optical observations. More recent X-ray observations made with ROSAT confirm the reality of this blob and reveal finer structure closer to the cluster's center. The Coma cluster apparently is still forming as smaller galaxy groups merge into the main cluster.

GALAXY SEEN IN A NEW LIGHT

Scientists have detected for the first time ultra-high-energy gamma rays coming from an object outside the Milky Way Galaxy. Markarian 421 is an active galaxy located about 400 million light-years away in the constellation Ursa Major. A region the size of our solar system inside the galaxy produces as much energy in high-energy gamma rays as our Galaxy does in all energy regions.

"Astronomers have observed active galactic nuclei in various energy regions: in radio, optical, gamma, and X rays," says James Gaidos of Purdue University and a member of the Whipple Observatory gamma-ray collaboration, "but never before at these energies. How this galaxy produces this type of radiation is a mystery. Only rarely can the most powerful particle accelerator laboratories on Earth generate gamma rays of these energies. The presumption is that a black hole with a mass more than one million times that of the Sun powers Markarian 421."

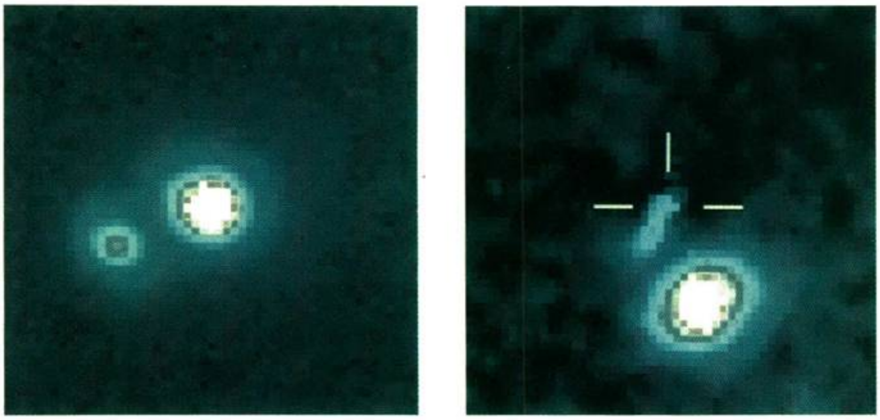
Gamma rays are not directly observable from the ground. Instead the team observed byproducts created by the gamma rays as they collided with molecules in Earth's atmosphere. The high-energy collisions created a layer of blue-colored light in the atmosphere that the scientists viewed with a system of telescopes. By viewing this light from different points, they determined the source of the gamma rays. Their next step is to monitor the galaxy to see how its energy varies with time.

LIFE CHEMISTRY ON TITAN

A layer of amino acids may exist on Titan, the largest satellite of Saturn. The satellite, which is 1.5 times the size of Earth's Moon, has a nitrogen and methane atmosphere. Aurorae occurring in Titan's atmosphere cause these gases to react, forming a tarlike substance called "tholin." Over the last few billion years, several meters of frozen methane mixed with tholin and other organic compounds covered Titan's surface.

W. Reid Thompson and Carl Sagan of Cornell University have demonstrated mechanisms by which these organic materials can produce amino acids, nucleotide bases, and simple carbohydrates — the building blocks of life on Earth. The key ingredient for converting the simple organic compounds, such as tholin, into the building blocks is water. Thompson asserts that areas on Titan occasionally melt when impacts occur. "Liquid water is mixed turbulently with organic material in the sediment and it forms a slurry. From that mix you get amino acids and other compounds," Thompson says. Thompson and Sagan believe that a slush of water, ice, and organic compounds covered more than half of Titan's surface at some time in its past. Thompson adds, "We expect that amounts corresponding to about a 2-centimeter thick layer of amino acids have been produced on Titan."

If Thompson and Sagan are correct, planetary scientists may have to reassess their notions of where life may be possible in our solar system. "We would not expect that this means it's likely there is life on Titan," Sagan says, "but it may mean that prebiological organic chemistry has gone much farther toward life than anyone had earlier thought because of the presence of the key missing ingredient, liquid water." Confirmation of this theory must wait until the year 2005, when the Cassini spacecraft visits Saturn and Titan. Cassini will send a probe, named Huygens after the 17th-century astronomer who discovered the satellite, to explore the atmosphere and surface of Titan.



William Romanishin, University of Oklahoma

A RARE OPTICAL JET apparently emanates from the nucleus of the BL Lac object designated 1E 1415.6+2557. This is only the second optical jet ever found in a BL Lac object, a class of extremely luminous, compact, and variable active galactic nuclei. William Romanishin photographed the object and a fainter companion galaxy (left) with the 2.1-meter telescope on Kitt Peak. He then subtracted the BL Lac nucleus and a model for its underlying elliptical host galaxy to reveal the jet (right). The color scale on the subtracted image has been changed to emphasize the jetlike feature, and the position of the BL Lac nucleus is where the three lines intersect.

BUILDING-BLOCK ION DETECTED ON URANUS

A molecular ion thought to play an important role in forming complex interstellar molecules has been found on the planet Uranus. The discovery may help explain how the lightest and most common element in the universe comes together with heavier elements to form complex molecules. Laurence Trafton of the University of Texas, part of a team of British and American astronomers, announced the findings at the American Astronomical Society's Division of Planetary Sciences' meeting held last October in Munich, Germany.

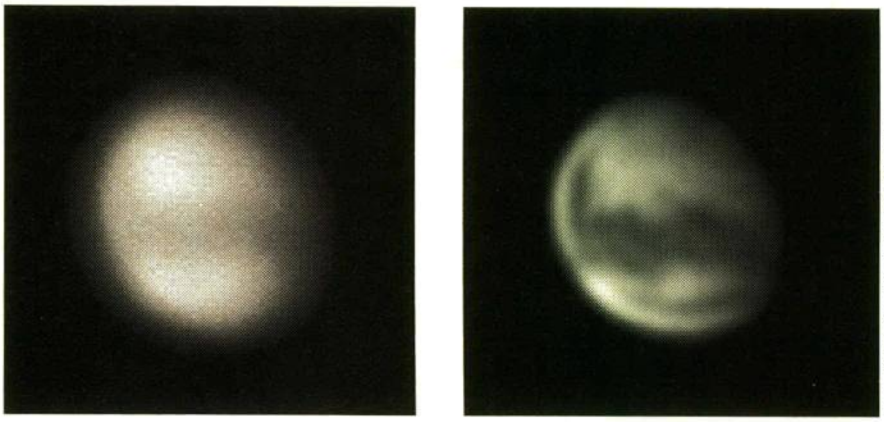
Astronomers believe the ion, known as H_3^+, plays a central role in the chemical evolution of molecular clouds, the birthplaces of stars. Trafton says "Astronomers have spent years looking for H_3^+ in interstellar space to test their hypotheses, because we know that when H_3^+ combines with other molecules, it initiates the interstellar chemistry that builds bigger molecules."

H_3^+, which is the simplest stable polyatomic molecule, has the ability to transfer a proton to heavier molecules. This is something its lighter cousins — molecular hydrogen (H_2) and atomic hydrogen (H), which are much more common — cannot easily do. The ion created in this process then reacts strongly with other molecules to form even heavier molecules.

Uranus is the second location outside laboratories on Earth where H_3^+

has been detected. The first was in Jupiter's atmosphere, where the ions are manufactured near the magnetic poles as a component of the planet's aurorae. Though the same process takes place on Uranus, an additional mechanism in the planet's upper atmosphere also appears to be at work.

"The non-auroral zone is important," says Trafton, "because this could mimic the way in which H_3^+ might arise around hot stars." So the discovery of H_3^+ in the Uranian atmosphere increases the odds that the ion exists in interstellar space and also our chances of eventually detecting it out there.


James Beletic, Georgia Institute of Technology

MONITORING MARS is now possible with a special technique that overcomes blurring of telescope images by the atmosphere. Speckle imaging of an object "freezes" atmospheric distortions by using exposures of about 20 milliseconds. A short exposure image of Mars taken with the Mount Wilson 60-inch telescope is shown at left. Atmospheric seeing smeared details by 1" on Mars' 6.1"-wide disk. Using 2,000 images, James Beletic of the Georgia Tech Research Institute and his coworkers reconstructed the high-quality image at right, revealing details as small as 0.3" wide, or 400 kilometers wide on Mars. With this resolution, astronomers can monitor the emergence of large dust storms and measure the growth and recession of Mars' polar caps.

SOLAR NEUTRINO PROBLEM CONTINUES

Researchers are now forced to admit that the Sun emits fewer electron neutrinos than models predict. Physicists report in the July 16 issue of *Physics Letters* that the Gallex solar neutrino detector captured only 63 percent of the neutrinos predicted by standard models of the Sun's interior. Gallex is a 30-ton gallium detector located under a 2,900-meter mountain peak in the Apennines northeast of Rome, Italy.

Taken by itself, the results of the Gallex experiment are not startling and do not lie far from standard model predictions. In fact they are consistent with the lowest neutrino emission rate predicted by models. But the Gallex results and those of two other experiments, when taken together, are not consistent with model predictions. The Homestake experiment, located in the Homestake gold mine in South Dakota, uses chlorine to detect higher energy neutrinos than those seen by Gallex. It sees only 27 percent of the neutrinos predicted for its energy range. Kamiokande II is a water-based detector located in the Kamioka mine 300 kilometers west of Tokyo. It detects neutrinos higher in energy than either Gallex or Homestake, but it sees only 47 percent of neutrinos expected. Even a five-percent reduction of the Sun's core temperature — a large change in the Sun's interior — cannot reconcile the three sets of results with solar models.

The answer to the solar neutrino problem apparently lies in the realm of particle physics. Solar models assume that neutrinos, like photons, have no mass. If neutrinos have a small mass, then they can interact with matter and change "flavor," transforming from one kind of neutrino to another. Because the three neutrino experiments can detect only electron neutrinos, any change in flavor would result in fewer solar electron neutrinos and fewer detections. As experimenters now work to reduce the error bars on the observed neutrino detection rates, theorists work to understand how neutrinos change flavors.

NEW RADIO DISH TO SEARCH FOR PLANETARY ORIGINS

A project to examine molecular gas and dust in orbit around the youngest nearby stars and to search for solid debris around older stars has been announced by the California Institute of Technology. The new study should clarify the physical conditions prior to and during the birth of planets and provide reliable estimates of when and how often planets form.

Caltech recently received a $1.455 million grant from the Kenneth T. and Eileen L. Norris Foundation to build a 10-meter-diameter millimeter-wave radio telescope at the University's Owens Valley Radio Observatory. In combination with three existing 10-meter telescopes and two more nearing completion, the new radio dish will allow the Owens Valley array to produce sharper images in much less time than the current array can. The array of six instruments will spend about one-fourth of its time on the long-term project designed to detect and study planetary systems forming beyond our solar system.

DEAD RATS TELL NO LIES

Highly energetic charged particles, most the nuclei of atoms traveling through space at near the speed of light, continuously rain down on Earth. Though discovered over 80 years ago, these cosmic rays still baffle astronomers. Now researchers are searching for clues to the enigmatic cosmic rays in an unlikely place: dried clumps of desert pack rat urine thousands of years old.

True to their name, desert pack rats hoard practically everything, including their urine. The urine permeates the rats' middens, nests made up of debris such as sticks, plants, and whatever else the rats bring home. Within hours the thick, syrupy urine crystallizes, becoming a solid that preserves well in the arid desert environment. When protected by caves or rock outcrops, the crystallized urine can last for tens of thousands of years.

The urine serves as an effective time capsule: the level of the radioactive isotope chlorine-36 in rat urine tells scientists the strength of the cosmic rays hitting Earth at the time the rat was alive. The chlorine isotopes form when cosmic rays smash into argon atoms in the atmosphere. The isotopes then fall to Earth in rainwater and are taken up by plants and animals.

Fred M. Phillips of the New Mexico Institute of Mining and Technology extracted salts from the last 20,000 years from a midden located near Reno, Nevada. Then Pankaj Sharma, a radiogeochemist at the University of Rochester, used a 15-million-volt accelerator mass spectrometer at the university's Nuclear Structure Research Laboratory to determine the amount of chlorine-36 in the samples.

Phillips and Sharma's analysis shows that the cosmic rays striking Earth 20,000 years ago were 40 percent more powerful than those today. This confirms the results of some previous studies that found the cosmic-ray intensity higher 20,000 years ago, primarily because Earth's magnetic field was weaker then. The weak magnetic field allowed more cosmic rays to penetrate the atmosphere. The researchers now plan to study other desert pack rat middens to extend their cosmic ray studies back to 40,000 years ago.

Amateur News

OKIE-TEX WEATHERS A STORM

Terry Atwood

THE PRUDE RANCH in Fort Davis, Texas, hosted the ninth Okie-Tex Star Party last October.

Last year the annual Okie-Tex Star Party moved from Oklahoma, its normal home, to Fort Davis, Texas, to take advantage of the dark skies near McDonald Observatory. And though the skies were dark over Fort Davis throughout the star party, from October 18-25, 1992, unfortunately they were rarely clear. The best the 250 participants who attended the ninth Okie-Tex could do was to view through holes in the cloud decks that slowly moved over the Prude Ranch, site of the star party near Fort Davis.

In the grand style of amateur astronomy, mostly cloudy weather did not discourage those who attended. Every night the covers came off some 100 telescopes set up at the ranch, and observers took their best shots through the clouds. The most striking telescope was a 36-inch f/5 reflector owned by Tom Clark of Sarasota, Florida. The instrument dwarfed the other scopes that sat near it, one as large as 18 inches in aperture. Large telescopes dotted the telescope fields, many in the 16-inch class and some 20-inch and 25-inch instruments. Some of these big Dobsonians were brought to the Okie-Tex in advance of a smaller gathering, the Ultimate Star Party, held the following week closer to McDonald Observatory.

Although the observing was hit and miss, Okie-Tex attendees enjoyed listening to some talks. Astronomer R. Edward Nather of the University of Texas described the Whole Earth Telescope, a project using many telescopes scattered around the globe to observe the complete cycles of the variability of white dwarf stars, which fluctuate in brightness on short time scales.

Dave Eicher, associate editor of ASTRONOMY, described 75 deep-sky observing challenges and illustrated them with photographs submitted to the magazine by amateurs over the past year. In addition to offering observational challenges, Eicher contended that old-fashioned astrophotography is alive and well.

Jim Secosky, a junior high school teacher from Manchester, New York, told the audience about his experience observing with the Hubble Space Telescope. Secosky observed Jupiter's moon Io as it came out of an eclipse and will use the space telescope again next year for a second project.

By the end of the week, Okie-Tex attendees yearned for clear skies. They look forward to the 1993 Texas Star Party, which will occur on the same ground in May, but resigned themselves this year to observing deep-sky objects on the large slide screen in the auditorium.

GALILEO'S TRIAL FINALLY OVER

In 1633 Galileo was forced to recant his belief in a heliocentric solar system as being "abjured, cursed, and detested." Stating that theologians at the time had erred in thinking that scripture explains the physical world, Pope John Paul II rehabitated Galileo in October 1992. The pontiff also said that faith and science are distinct but not necessarily opposite, ironically a position not very distant from the one Galileo used in his defense. The pontiff's statement finalizes the opinion of a 1984 preliminary report that found Galileo had been wrongfully condemned by the Roman Catholic Church.

ARECIBO TO RECEIVE IMPROVEMENTS

Over the next few years, the world's largest radar-radio telescope at Arecibo Observatory will become 20 times more sensitive for studies of solar system objects and 3 times more sensitive for studies of distant galaxies. The 1,000-foot reflector dish will not change, but the antennae will. The large reflector focuses radio signals onto feed antennae located on two carriage houses suspended above the reflector. Receivers inside the carriage houses convert the signals into digital sequences for analysis by computers on the ground.

Two new reflector-type feeds and a horn feed will replace the present line feeds. The towers supporting the carriage houses will be reinforced so they can support a new carriage house that

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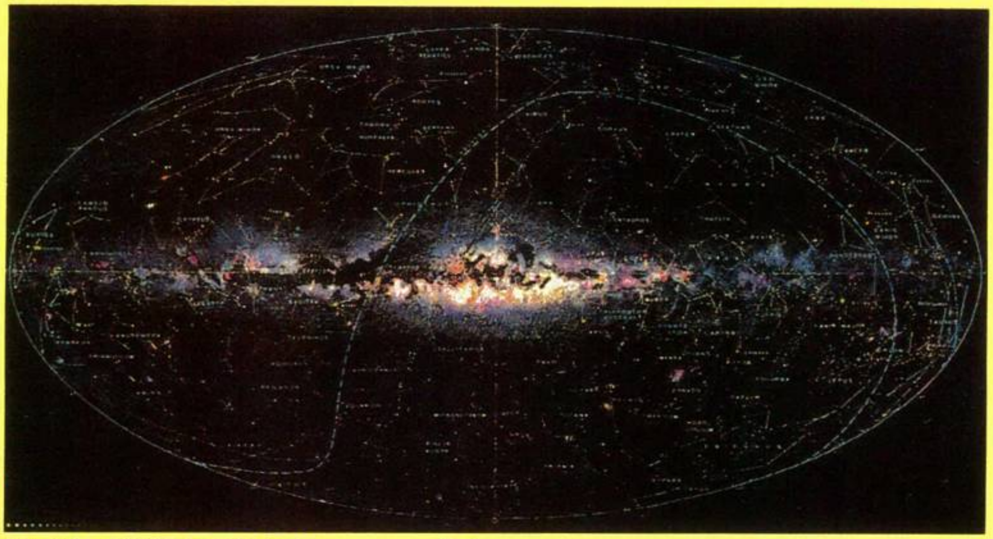

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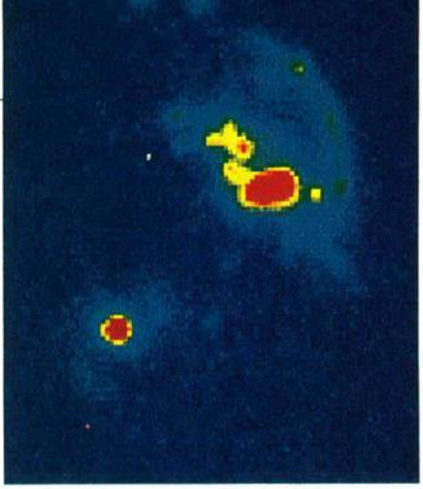
What would you look at if you had the use of the Hubble Space Telescope for several hours? If you have a unique idea that would provide real scientific return, you just might be awarded the opportunity to use the world's most expensive and sophisticated telescope. The arrangement is unique for a major observatory — after all, how many amateurs get to use the 200-inch Hale or 10-meter Keck telescope?

But twice before in the Hubble program, amateur astronomers have been invited to submit proposals for observing programs. (See "Anyone for a 94-Inch Telescope?", December 1991 ASTRONOMY.) Several amateurs from the first group have already made their observations, and the six amateurs from the second round of selections are preparing to do so.

Amateur astronomers making the final cut in the third round of selections will be the first to use Hubble with its corrective optics (see page 42). If you have an idea for observing with the Hubble Space Telescope, write to the American Association of Variable Star Observers, 25 Birch Street, Cambridge, MA 02138. They can supply you with the forms and information you need to submit a proposal. But hurry. The deadline for applications for round 3 is April 30.



Donna Weistrop, University of Nevada, Las Vegas

A PAIR OF INTERACTING GALAXIES has been discovered in the Bootes void, the first such pair to be found in this immense volume of largely empty space. The galaxies, designated CG 692 (upper right) and CG 693 (lower left), lie approximately 24 kiloparsecs apart. CG 693 is a Seyfert galaxy, the third active galaxy to be identified in the void, and CG 692 is undergoing an intense burst of star formation. Donna Weistrop of the University of Nevada, Las Vegas, and her colleagues reported the discovery in the September 1, 1992 issue of *Astrophysical Journal Letters*.

Space News

NEW SATELLITE COULD LAST FOREVER . . .

Or at least several billion years! The new LAGEOS II satellite's orbit is designed to be so stable that the satellite could still be circling Earth when the Sun turns into a red giant billions of years from now. But building a satellite that will outlive humans isn't the goal of the LAGEOS program. Instead, the new Italian-built satellite will help scientists today understand earthquakes and volcanic eruptions.

LAGEOS, the Laser Geodynamics Satellite, was released October 23 from the space shuttle Columbia. A booster rocket, called the Italian Research Interim Stage, propelled the satellite away from the shuttle into a 3,666-mile-high circular orbit.

LAGEOS was an unusual shuttle payload. The satellite has no moving parts, no electronics, no need for power of any kind. It consists of a two-foot diameter ball made of two aluminum hemispheres surrounding a solid brass core. Despite its small size, LAGEOS weighs 900 pounds. The compact, dense design helps keep the satellite immune to drag from Earth's atmosphere and from the solar wind, making its orbit as stable as possible.

Within days of its launch, geophysicists were already putting LAGEOS to work by bouncing laser beams off its surface. Covering LAGEOS are 426 retroreflectors, giving it the appearance of a dimpled golf ball. The reflectors will bounce any light beam directly back where it came from, in this case to one of more than 30 laser stations scattered around the globe. By measuring how long it takes a pulse of laser light to reach LAGEOS and return, scientists can determine the distance to LAGEOS and the exact location of the laser station. This information can be used in turn to follow the movement of Earth's crustal plates and fault zones with a precision measured in fractions of an inch. LAGEOS scientists will also use the satellite to track wobbles in Earth's axis of rotation to an accuracy of 2 inches. This allows geophysicists to detect the movement of material deep in Earth's core.

The new LAGEOS II joins a similar LAGEOS I satellite launched in May 1976. With two laser-ranging satellites in orbit, scientists will be better able to track the movements of land in seismically active areas such as California and the Mediterranean. A third LAGEOS is scheduled for launch in 1994. □

NASA

LIKE A HIGH-TECH MIRROR BALL, the LAGEOS satellite sits atop its booster stage shortly after its release from the shuttle payload bay last October.

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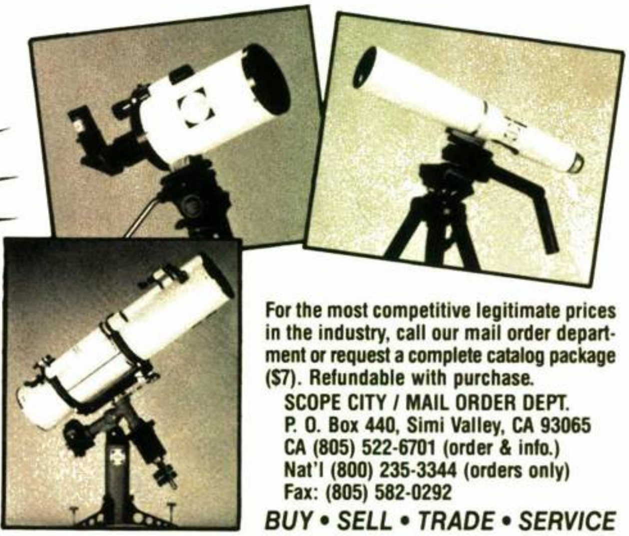

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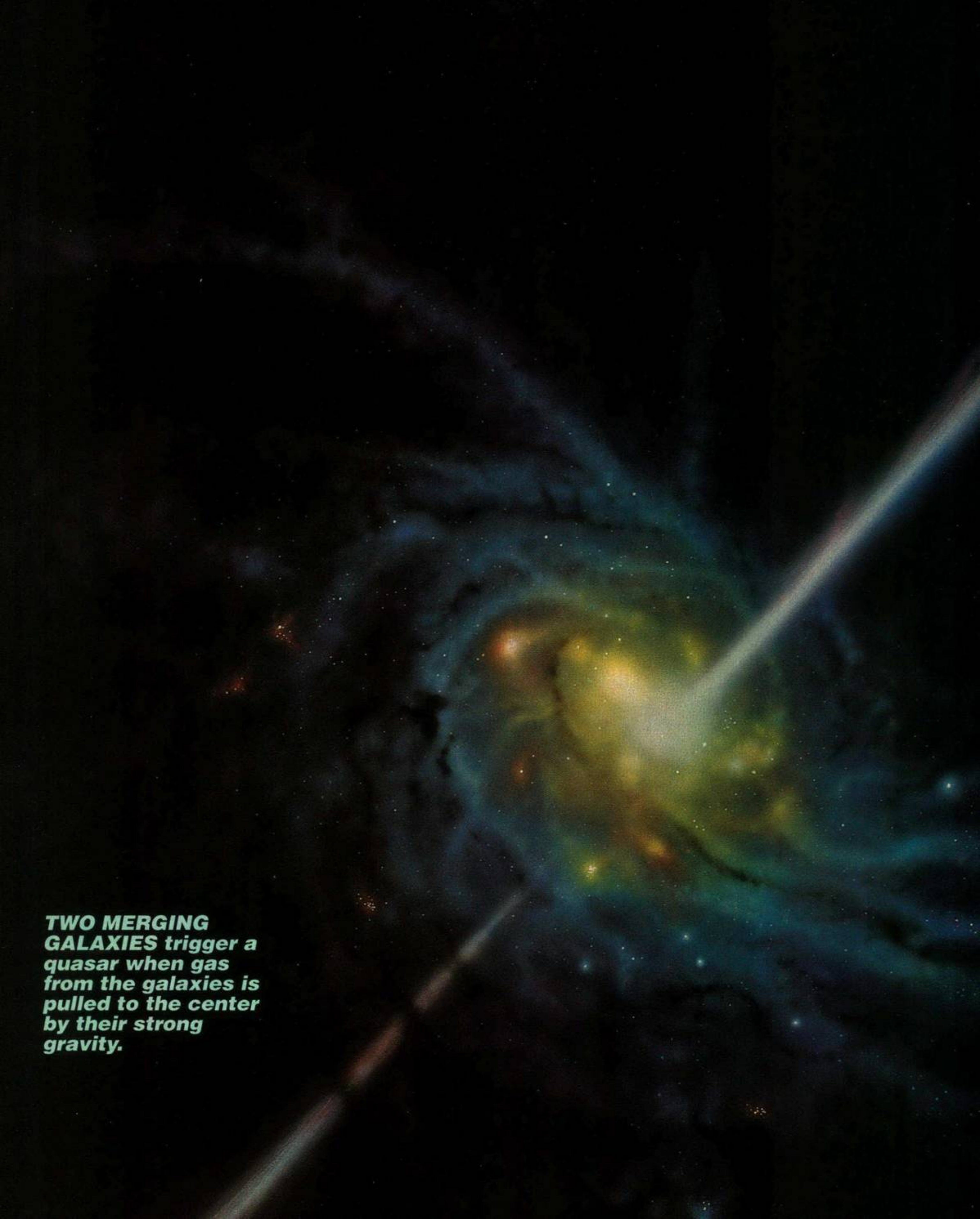
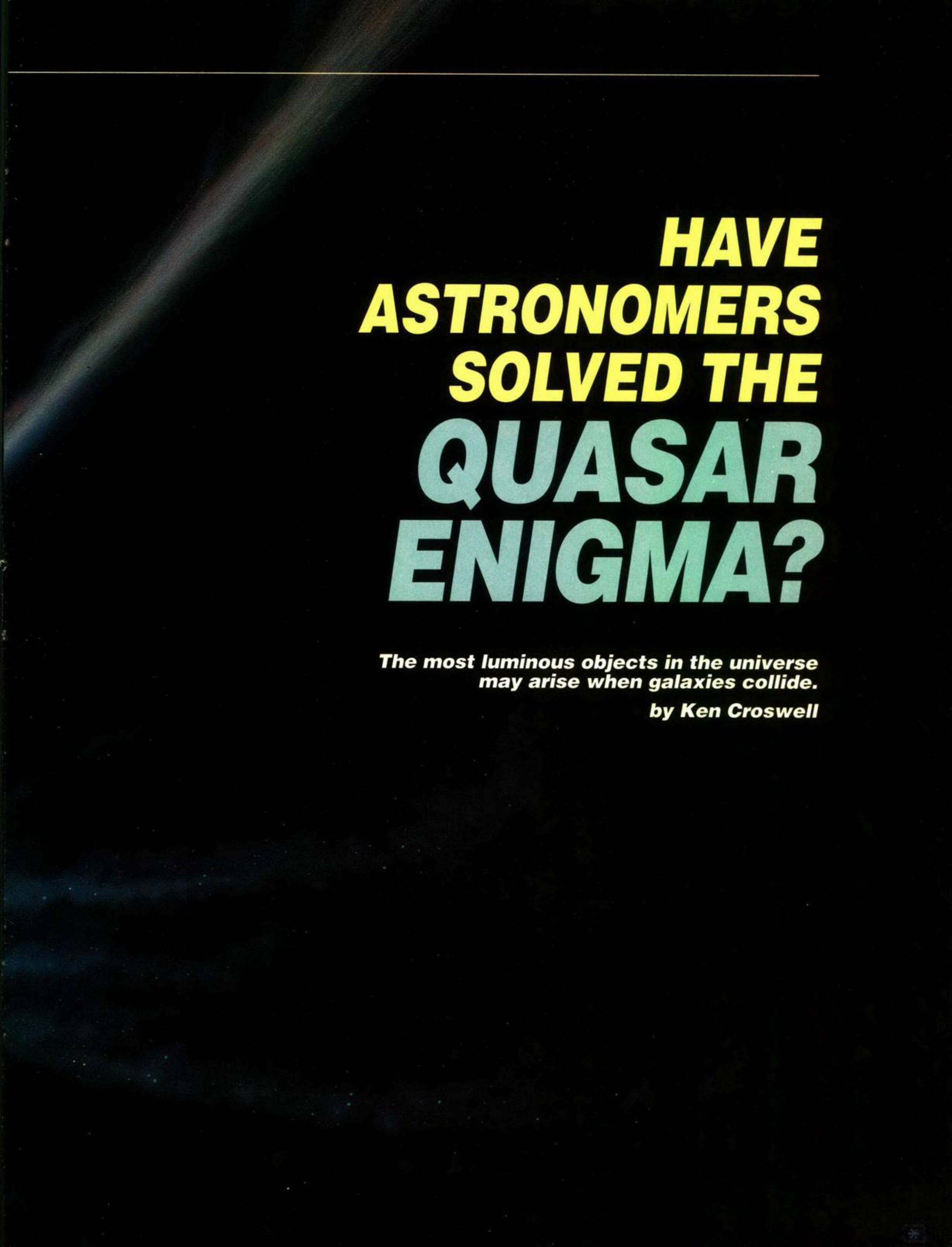


TWO MERGING GALAXIES trigger a quasar when gas from the galaxies is pulled to the center by their strong gravity.



HAVE ASTRONOMERS SOLVED THE QUASAR ENIGMA?

The most luminous objects in the universe may arise when galaxies collide.

by Ken Croswell

First identified 30 years ago this month, quasars still confound. A quasar can outshine our Galaxy a hundred times over, yet it spans a region little larger than our solar system. These properties have mystified astronomers for years. But many astronomers now think they know what a quasar is: a carnivorous black hole at the core of two colliding galaxies.

"Evidence is mounting that quasars occur often in merging galaxies," says François Schweizer, an astronomer at the Carnegie Institution of Washington and an expert on interacting galaxies. "Quasars aren't some weird, incomprehensible objects; they are phenomena at the centers of galaxies, many of which are colliding with other galaxies."

The center of each colliding galaxy may harbor a black hole, in which case the two black holes may merge into one. Or the collision itself may create a black hole. Either way, a massive black hole arises and grabs much of the gas from the galaxies. As it falls into the black hole, this gas gets so hot that it radiates tremendous amounts of energy from a tiny space, giving birth to a quasar.

But other astronomers think that few quasars form this way. "Colliding galaxies can release huge amounts of energy," says George Rieke of the University of Arizona, "but the real issue is whether that energy comes from a quasar or just a lot of star formation."

The Nature of Quasars

Quasars have long bewildered astronomers. The first quasi-stellar object, or quasar, was discovered in 1960. Not until 1963 did astronomers learn how distant the objects are. Maarten Schmidt of the California Institute of Technology determined the redshift of the quasar 3C 273, which is number 273 in the *Third Cambridge* (3C) *Catalogue of Radio Sources*. It has the brightest apparent magnitude of any quasar, appearing as a 13th-magnitude starlike object in the constellation Virgo. But 3C 273 is no star: it has a huge redshift of 0.158, meaning that its spectral lines are shifted 15.8 percent to the red.

The large redshift indicated to Schmidt that 3C 273 is far away. In an expanding universe, the larger an object's redshift, the greater the object's distance. This redshift is *not* a true Doppler shift, however. A Doppler shift arises when an object moves toward or away from us. If an object moves toward us, its light waves get scrunched up and shifted to the blue. If the object moves away from us, its light waves get stretched out and shifted to the red.

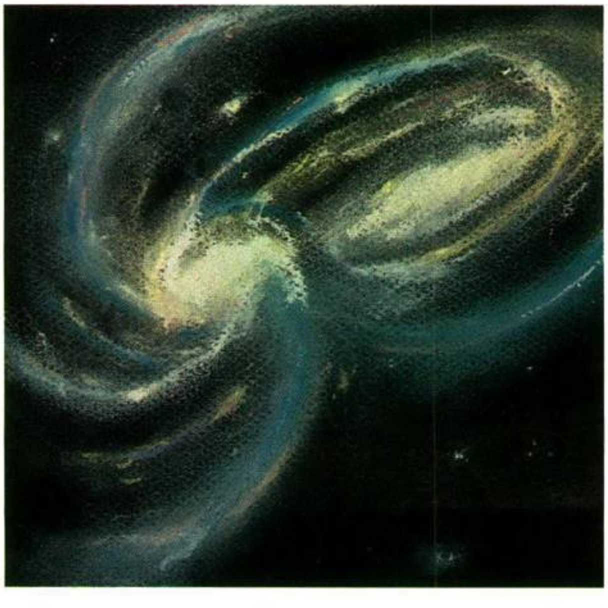
But 3C 273's redshift arises not from its movement away from us, but from the expansion of the universe. Imagine that 3C 273 sends out light with a wavelength of 1000 angstroms. Before reaching us, the light waves travel through the fabric of space for billions of years. During this voyage, the universe expands, stretching the light waves. By the time the light reaches Earth, the wavelength has become 1158 angstroms, a redshift of 15.8 percent.

The large redshift means that 3C 273's light has traveled some 2 billion light-years. To appear as a 13th-magnitude object from such a vast distance, it must emit trillions of times more light than the Sun. Soon after Schmidt identified 3C 273 as a distant object, astronomers measured the distance of another quasar, 3C 48. This quasar is a 16th-magnitude object in the constellation Triangulum and has an even bigger redshift — 0.367 — and therefore an even greater distance than 3C 273.

Such redshifts astonished astronomers thirty years ago because they are large compared to the redshifts of normal galaxies, but today they are nothing special. Most quasars have greater redshifts than 3C 273 and 3C 48. In fact, quasars appear most abundant at a distance corresponding to redshifts between 2 and 3, and the farthest known quasar, identified in 1991, has a redshift of 4.897. Light from these quasars has traveled so far that it arose when the universe was only a few billion years old. Quasars were therefore much more common when the universe was young than they are today. The great distance of quasars also implies that they emit vast quantities of light.

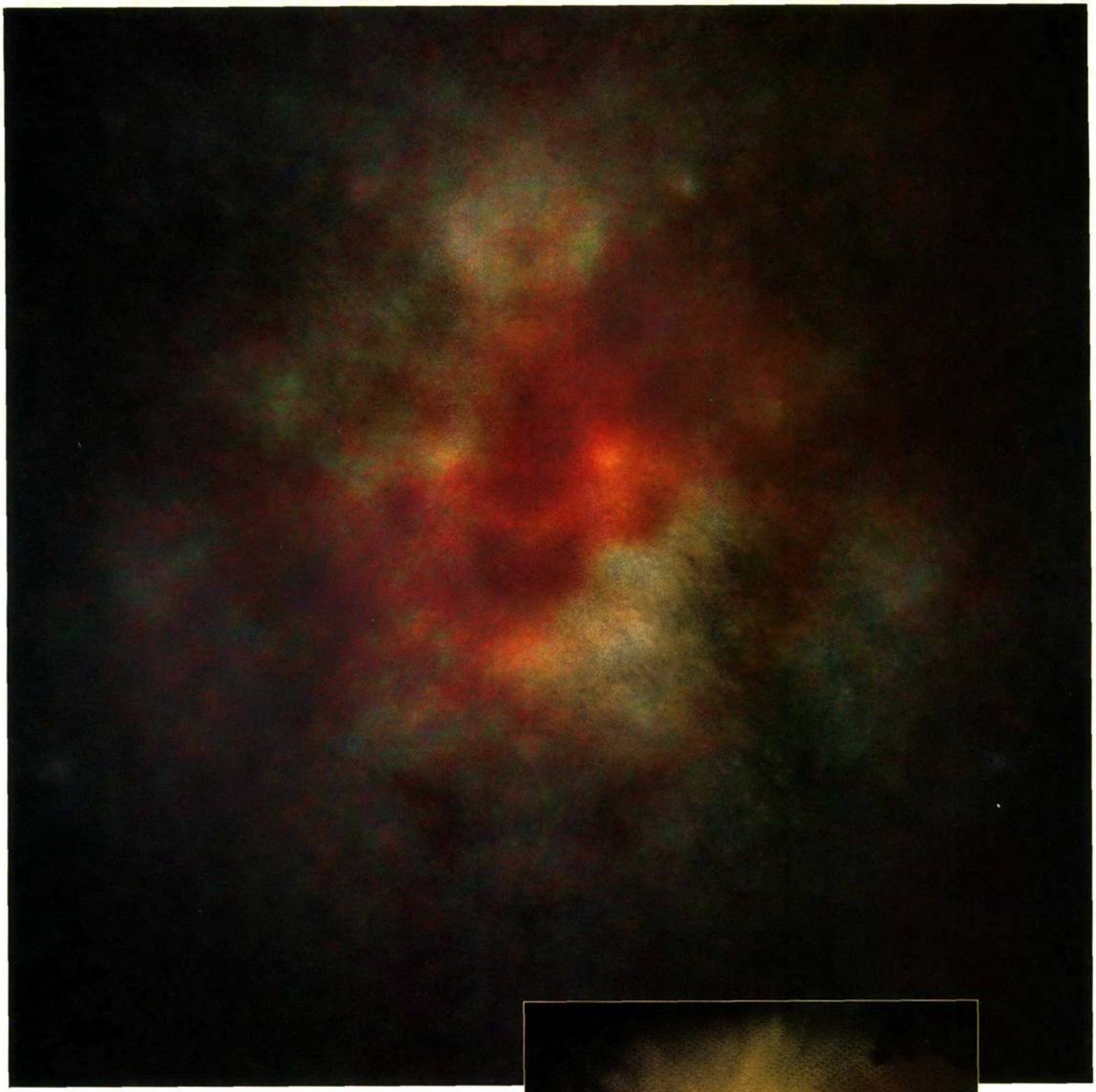
Most astronomers believe a quasar owes its immense luminosity to a massive black hole at the center of a galaxy. (See "The Emerging Picture of Quasars" by Belinda J. Wilkes, December 1991.) This black hole contains millions of times more mass than the Sun but occupies about the same volume as the Sun. The black hole attracts material, which then forms a disk around the black hole. The whirling disk gets heated by gravity and friction and can outshine a trillion suns, yet it is not much bigger than our solar system. A quasar's powerhouse must be this small because its light can change rapidly in less than a day. This implies that the region generating the light must be one light-day across, about twice the diameter of Pluto's orbit.

"One doesn't like to believe in invisible ghosts," François Schweizer says, "but the evidence [for a black hole] is just too strong. It is really the only good mechanism that we have. It explains many things that we know about quasars."

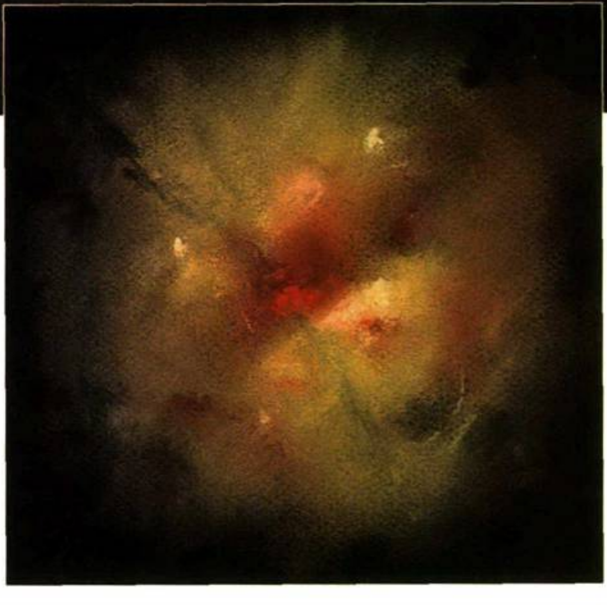


ASTRONOMY: All illustrations by Phil Kirchmeier

GAS AND DUST ENRICH spiral galaxies. When these galaxies merge, stars, gas, and dust are flung into space, forming long tails. In the core, the intense gravity creates a black hole and a cloud of gas and dust around it.



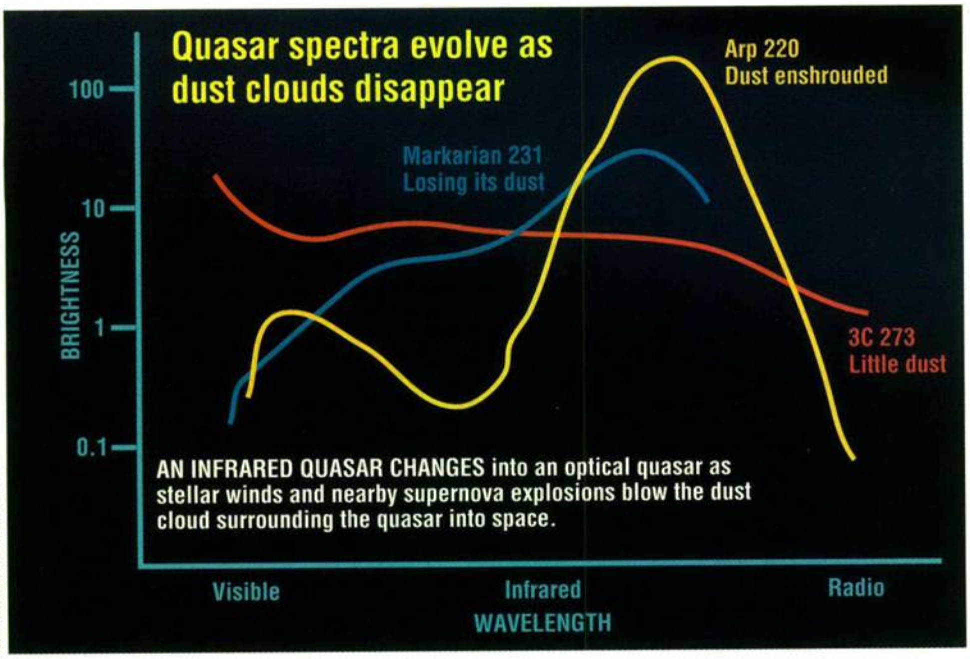
E. Shaya, D. Dowling, and NASA



DUST SHIELDS THE QUASAR in the infrared galaxy called Arp 220. As the illustration at right shows, pockets of hot stars cause the dust to glow in the infrared.

Galaxies in Collision

Some astronomers have taken this model further: they believe that a quasar occurs only if two large galaxies with similar masses collide. Each galaxy may already have a black hole at its center, or the collision may create a black hole. Whatever the case, the collision causes material to rain down on the black hole, generating enormous energy and igniting the quasar.



Quasar spectra evolve as dust clouds disappear

AN INFRARED QUASAR CHANGES into an optical quasar as stellar winds and nearby supernova explosions blow the dust cloud surrounding the quasar into space.

ASTRONOMY: Thomas L. Hunt

The idea is not new. In the early 1970s, Alar and Juri Toomre made computer models of colliding galaxies and found that collisions could explain many odd-looking galaxies. In particular, the Toomre brothers found that one galaxy's gravity often draws out a long tail of stars from the other. Two such tails stream out of one of the most famous colliding systems, the Antennae galaxies (NGC 4038 and 4039) in the constellation Corvus.

The Toomres suggested that two colliding galaxies can trigger more spectacular activity if their gas falls toward their centers. But they could not prove it, because their model galaxies had only stars and no gas.

"There's a big difference between gas and stars," says Schweizer. "When two galaxies of 100 billion stars each collide, not much happens. The galaxies may merge but few, if any, stars collide with another star. On the other hand, gas pervades huge volumes of space. So the collision of two gas-rich galaxies crunches the gas, greatly increasing its density and sending it toward the black hole."

"The calculations require supercomputers," says Caltech's Thomas Soifer. "The Toomres had great insight into what the collision's effects on gas would be, but they did not include gas in their models because computers then were not capable of that kind of calculation."

"What is new," says Schweizer, "is that people now are beginning to include gas in their models." Scientists such as Joshua Barnes at the University of Hawaii and Lars Hernquist of Lick Observatory have used powerful computers to model the gas in colliding galaxies. These models show that the gas rapidly spirals into the central black hole, producing quasar activity.

"One prerequisite is that you must have a lot of gas," says the University of Hawaii's David Sanders. Sanders has discovered gas in several quasars and found that it is molecular — the form gas assumes when densest. But not all galaxies have molecular gas, so not all colliding galaxies will create quasars.

"You have to start out with two galaxies really rich in molecular gas, like two M51s," says Sanders. "Maybe two Milky Ways would do it. But you couldn't get away with galaxies that had only a little gas in the molecular form. If you collided two gas-poor ellipticals, you're not going to get a quasar.

"I think the quasar is the extreme end of this general process of galaxy mergers. The most gas and the most efficient scrunching of it to the center gives you a quasar."

Quasars in a Different Light

Key evidence for the idea that quasars are colliding galaxies came from the Infrared Astronomical Satellite (IRAS), which in 1983 detected galaxies whose infrared luminosities rival the optical luminosities of quasars. If two galaxies collide and trigger a quasar, the quasar initially should lie buried in their gas and dust. The dust absorbs the quasar's light, so astronomers cannot see the quasar at optical wavelengths. But the light heats the dust, which then radiates in the infrared. IRAS found galaxies that pour out over 90 percent of their energy in the infrared.

Thomas Soifer observed ten sources that IRAS had found with luminosities over a trillion times the Sun's. "Every one of them was a colliding, merging pair of galaxies," says Soifer. Without IRAS, no one would have known that these objects generate as much energy as quasars do. "IRAS provided a thread that ties all these objects together: they are all incredibly luminous, they're all interacting, and they all have these attributes that make them look like there's perhaps a dust-enshrouded quasar inside of them."

The best example, says Soifer, is a system called Arp 220 — the 220th object in Halton Arp's *Atlas of Peculiar Galaxies* — in the constellation Serpens Caput (see preceding page). "Arp 220 was the one we found first, because it was the brightest," he says. "I would describe Arp 220 as the prototype of these kinds of systems, just as we use 3C 273, which is the brightest of the quasars, as the prototype for quasars."

Arp 220 emits 98 to 99 percent of its luminosity in the infrared. It has a modest redshift of 0.018 and a distance of about 230 million light-years. "It's the closest of these objects, so it's amenable to the most detailed study," says Soifer. "If we can understand this one, we think we'll make great progress toward understanding all of them."

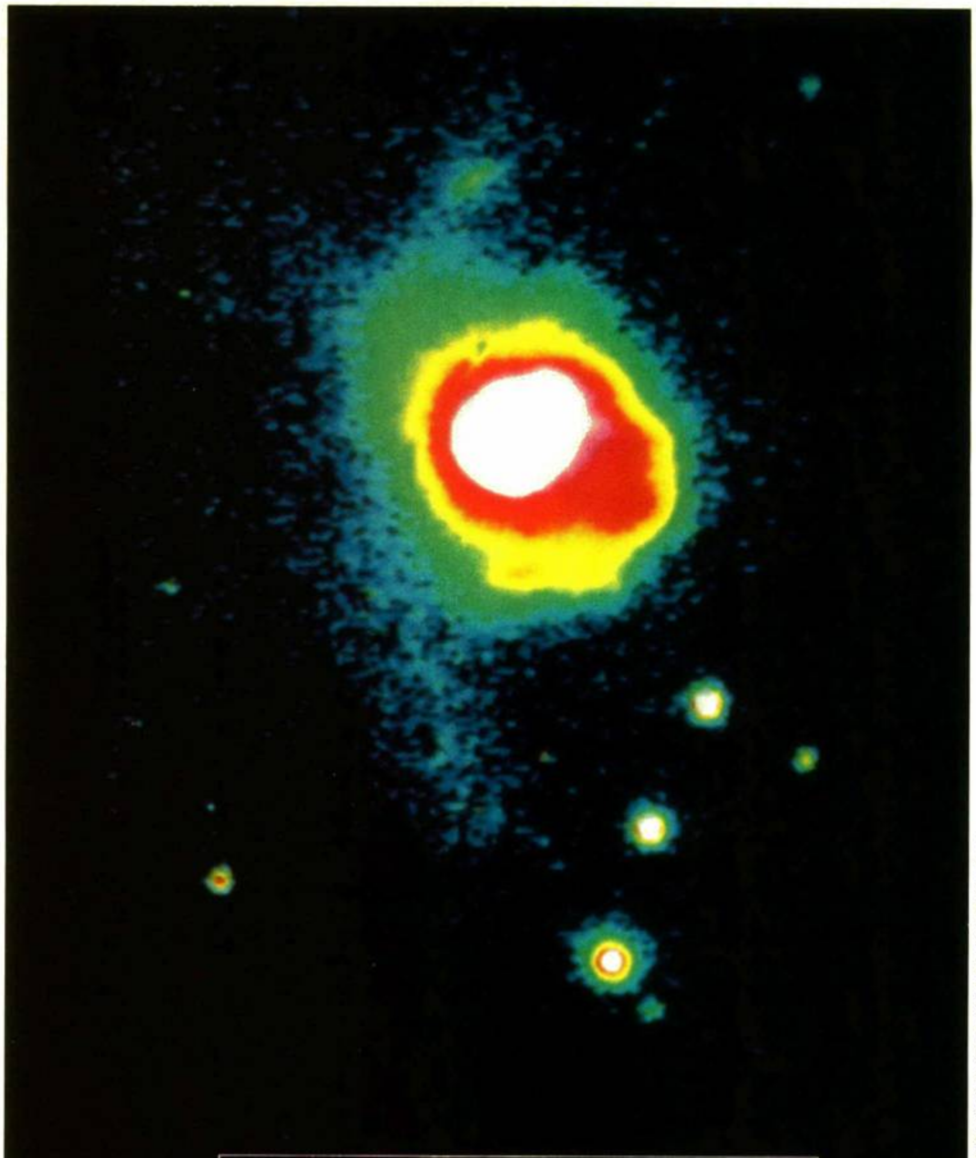
The collision that created Arp 220 not only dumped gas onto the central black hole, triggering the quasar, but also compressed the gas elsewhere and produced a horde of young stars — what astronomers call a starburst. Light from these young stars accounts for a major fraction of Arp 220's visible luminosity but it, like the quasar's light, gets absorbed by dust and gas.

And Arp 220 has plenty of gas. Says David Sanders, "There's enough gas to fuel a horrendous starburst as well as fuel a quasar." Yet the young stars and the quasar itself will eventually destroy the dust cloud that cloaks them. Supernova explosions and winds from the young stars will poke holes in the dust, and the quasar's strong light will break through the dust. Millions of

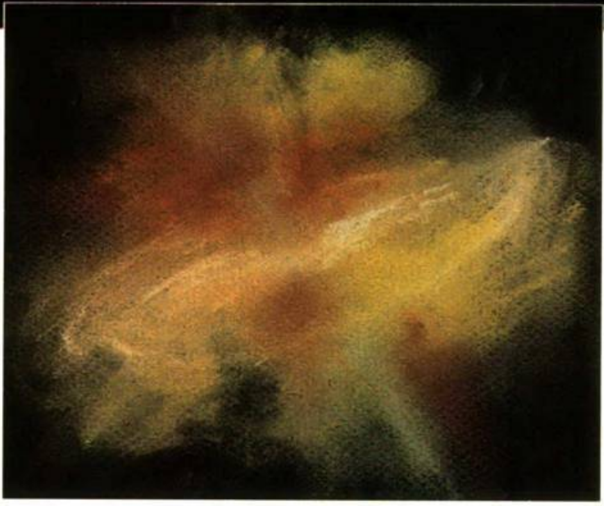
HOLES IN THE DUST, created by hot stars and supernovae, allow light from the quasar inside the galaxy known as Markarian 231 to escape. The dust will now rapidly dissipate into space.

years from now, the buried quasar will emerge from its cocoon. In fact, such half-buried quasars exist, says Sanders.

"Markarian 231 is the classic example," he says. "It's a crossover object," making the transition from infrared quasar to optical quasar. Markarian 231 (at right) is a 14th-magnitude object in the constellation Ursa Major with a redshift of 0.042, corresponding to a distance of 550 million light-years. Of all objects with redshifts under 0.1, Markarian 231 is the most luminous, throwing off 3 trillion times the energy of the Sun. Since the 1970s, astronomers have known that Markarian 231 emits a lot of infrared light. IRAS confirmed this, finding that the object radiates over 90 percent of its energy in the infrared. In 1986 Sanders and his colleagues obtained deep optical images of Markarian 231. They found that the system is a colliding galaxy: it has two long tidal tails, just as the Antennae galaxies do.



David Sanders, image taken at Palomar Observatory



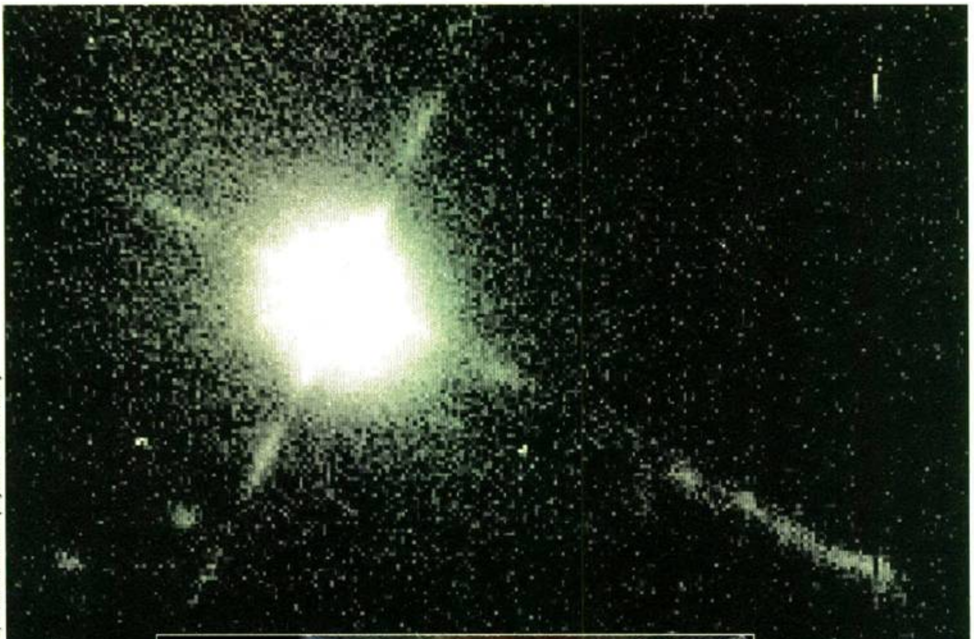
"For me, that was the most exciting discovery," he says. "Here was an object that had been around for a while and that people were putting in both the quasar camp and the galaxy camp. This extra information that it was a colliding system was for me a very important part of the puzzle."

Sanders has continued to study Markarian 231. "Once I saw how pivotal Markarian 231 was and how much interest it was drawing, I figured if I couldn't understand this object, I'd have trouble explaining anything else." Sanders and his colleagues have detected large amounts of molecular gas in Markarian 231 — a prime requirement for powering a quasar.

Such observations impress François Schweizer. "To me, the most exciting aspect of the last five years is that as people have gotten better and better detectors, they have found that in all these infrared-bright mergers there are absolutely astounding amounts of molecular gas. It's often 10 to 20 times the sum total of molecular gas in the Milky Way. It all seems to be packed together in a very small central region. And of course that's exactly what you would need to feed a black hole and ignite the quasar."

When Markarian 231 breaks through its dust cloud, it may become a normal quasar, like 3C 273 (see next page). "As that happens," says Schweizer, "most of the dust will be gone and, lo and behold, you'll see the quasar shine at full brightness."

In 1983, Alan Stockton of the University of Hawaii and John MacKenty, now at the Space Telescope Science Institute, found that a normal optical quasar named 3CR 249.1 is really two colliding galaxies. "It's beautiful," says



Robert McClure, Dominion Astrophysical Observatory

WITH ITS DUST GONE, 3C 273 shines brightly in visible light. The cross is an artifact from the telescope and camera, but the streak at bottom right is a jet of material spurting from the quasar.

Schweizer. "You see these two little tails sticking out. It's like a very distant version of the Antennae galaxies."

A typical quasar such as 3C 273 probably shines for 10 to 100 million years, while its gas gets consumed by both the black hole and the starburst. "If you wait another five to ten billion years," says Schweizer, "I suspect you'll have just a normal luminous elliptical galaxy." M87, an elliptical galaxy in Virgo (at right), may be a quasar that has run out of gas.

Elliptical galaxies have little dust and gas, but they are not the only possible outcome of a quasar. If some gas remains, a gas-poor spiral galaxy may form. But a gas-rich spiral, like the Milky Way Galaxy, is an unlikely remnant, so our Galaxy probably never harbored a quasar.

A Crowded Universe

The theory that quasars arise from colliding galaxies could explain why most quasars shone long ago and have redshifts of between 2 and 3. At that time, the universe was smaller and more crowded, so galaxies collided more often.

"The era, corresponding to a redshift of 2 or 3," says Schweizer, "must have been the peak period for collisions and mergers. When we see the collision of two galaxies today, we are seeing the dregs of what must have happened much more often in the past." In addition, these young galaxies had more gas than today's galaxies, since the former had only just started to convert their gas into stars. More gas means more fuel to feed the black hole and power a quasar.

"The quasar epoch peaks at a redshift of 2," says Sanders, "so mergers and luminous infrared objects should also peak at the same redshift. What that means to me is that the bulk of galaxy formation occurred much earlier — at redshifts beyond 5." This theory therefore predicts that galaxies formed first, and that quasars formed when those galaxies collided.

Quasar Qualms

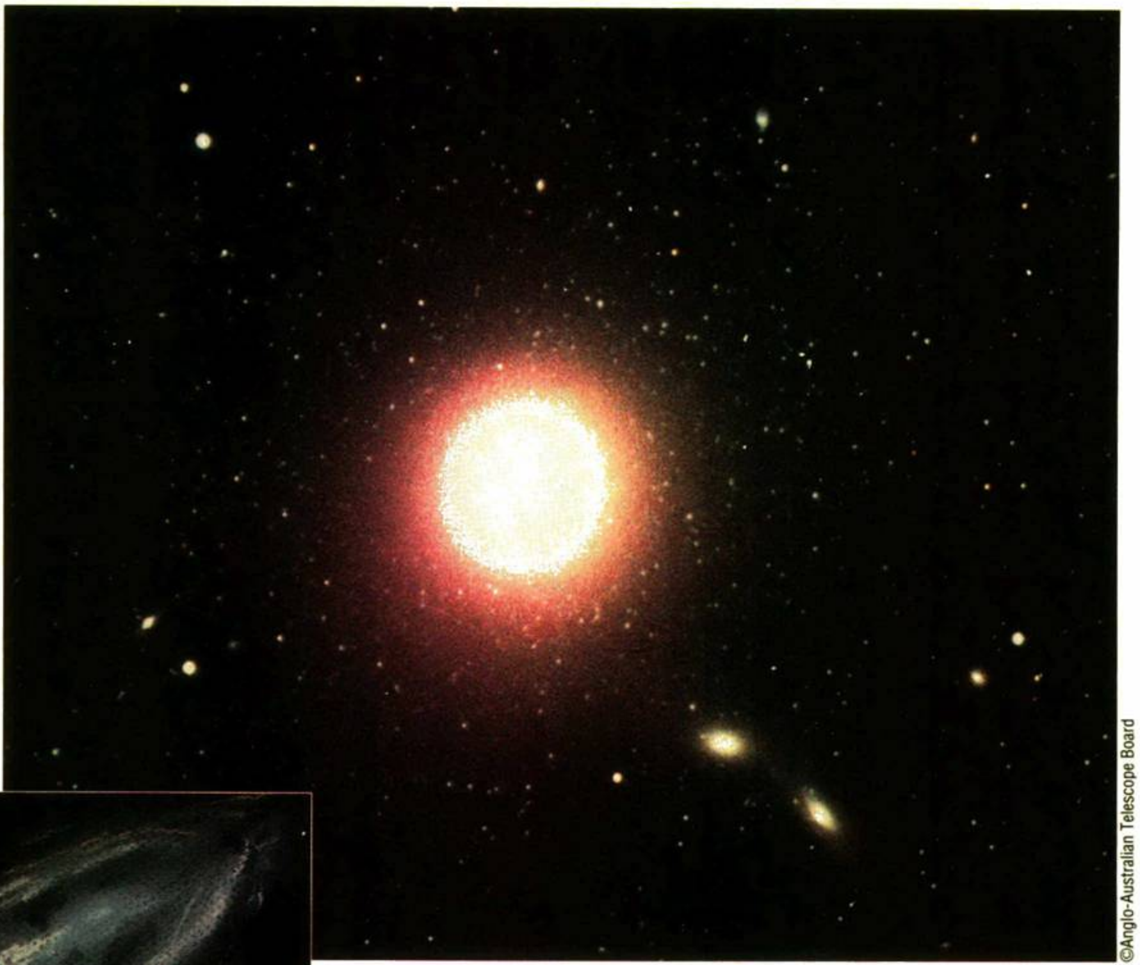
Not all astronomers accept this picture, however. One is George Rieke. Ten years before IRAS, Rieke helped show that Markarian 231 and other systems emit a huge amount of infrared radiation. He believes that some quasars may indeed be colliding galaxies, but not all of them.

"A galaxy collision is a way to trigger mass flow into the nucleus," he says. This mass flow can activate a quasar. "But I suspect there are other ways to trigger mass flow into the nucleus. It may well be that a collision is a sufficient but not a necessary condition to produce a quasar." Rieke believes most quasars are single galaxies whose central black holes are receiving mass from that galaxy. He also believes that nearly all the bright IRAS sources owe their luminosities to bursts of star formation rather than buried quasars.

Sanders, though, thinks the fact that infrared-bright galaxies have luminosities equal to that of quasars is revealing. If the two are unrelated, "it's a very remarkable coincidence," he says. "One would have to find starbursts that do not just rival but almost exactly equal quasar luminosities. Yet quasars were so unique and so special. Now you come along and explain it away as pure star formation." Like Rieke, Sanders believes that starbursts occur when galaxies collide, but also that a quasar turns on in the most extreme cases.

Rieke is unimpressed with the similarity of luminosities. "That's a coincidence," he says, "but I would not describe it as remarkable."

Furthermore, says Rieke, "I think that the ultraluminous infrared galaxies don't evolve in a parallel way with the quasars." If infrared galaxies are really quasars in disguise, they should have evolved in the same way and show the same redshift distribution. Since quasars peak at redshifts between 2 and 3, so should ultraluminous infrared galaxies. But Rieke thinks that the ultraluminous infrared galaxies may have a different redshift distribution than quasars do. He



A QUASAR BURNS OUT after 10 to 100 million years, having used up gas scrunched to the center by the merger of two spiral galaxies. The resulting gas-poor galaxy can then appear as an elliptical galaxy. A faint jet, as exhibited by M87, gives evidence of the collision that once triggered a quasar.

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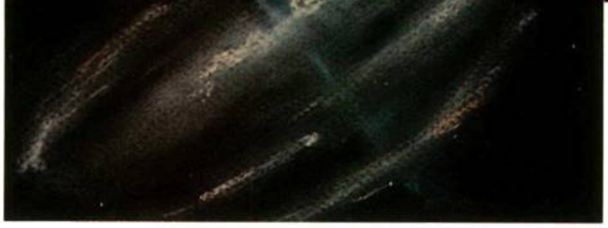


admits, though, that their distribution is uncertain. "That's based on really stretching the available [IRAS] data almost to the breaking point."

What's needed, says Rieke, is a better infrared telescope than IRAS. With few exceptions, it did not see beyond a redshift of 0.2 or 0.3 although astronomers did find one IRAS source with a redshift of 2.286. Early in the next century, scientists hope to launch the Space Infrared Telescope Facility (SIRTF). It will routinely detect infrared sources at large redshifts and allow a comparison with optical quasars, to see if both ultraluminous infrared galaxies and optical quasars have the same redshift distribution and evolved in the same way.

"Outside of their luminosities," says Rieke, "the most telling thing about the quasars is their cosmic evolution. There's nothing else that we know of that evolved so rapidly and died out so quickly. If we could make the same measurements of the ultraluminous infrared galaxies and see how they evolved, then that will certainly tell us whether they have this remarkable attribute of quasars. We'll be able to take the two graphs, put them next to each other, and see if they're the same. If both objects evolved the same way, then they're almost certainly the same kind of object."

Will the Milky Way Go Quasar?

Billions of years from now, our descendants can test the theory directly: if the theory is right, the Milky Way Galaxy itself may become a quasar.

Many astronomers believe the Galaxy will someday collide with the Andromeda Galaxy (M31). M31 is the nearest spiral galaxy to our own and presently lies 2.5 million light-years away. Both M31 and the Galaxy may already have massive black holes at their centers. Furthermore, both are giant galaxies, far bigger than most galaxies in the universe.

So mighty and massive are M31 and the Galaxy that their gravitational pull draws them together, even though the universe's expansion tries to push them apart. If neither galaxy had much mass, the universe's expansion would push the two galaxies apart at about 60 kilometers per second. Instead, the two galaxies are approaching each other at 120 kilometers per second. Every day, M31 draws 10 million kilometers closer to us. Billions of years from now, M31 may collide with our Galaxy.

The ultimate outcome will depend on just how M31 and the Galaxy collide. "They're both large spirals, and they're both gas-rich spirals of approximately the same mass," says Sanders. "The collision could turn our galaxy into a quasar." ☐

Ken Croswell is an astronomer in Berkeley, California. His last two articles for ASTRONOMY were "Galactic Archaeology" in the July 1992 issue and "The Grand Illusion" in the November 1992 issue.

ALL IN THE FAMILY

When asteroids collide, pieces fly. Tracking the fragments is giving astronomers new insights into the history of the asteroid belt.

by Dan Durda

Ever see a home video in which somebody drops something breakable? Wasn't it fun to run it in reverse and see all the scattered pieces come flying together again? With the help of large computers and sophisticated software, some astronomers are doing much the same thing — only it's not eggs or pumpkins they're putting back together but asteroids, giant rocks that orbit the Sun between Mars and Jupiter.

In this region, the asteroid belt, drifts a wasteland of rocky debris. The largest asteroid, Ceres, is only 1,000 kilometers in diameter — barely big enough to show a disk in a large telescope. All other asteroids are smaller, showing as pinpoints or streaks on long-exposure photos. These flying mountains slowly turn and tumble as each traces its lonely orbital path.

Because planetary scientists can't image the surface of an asteroid (except with expensive spacecraft), it seems hopeless to try to unfold the object's history or say anything meaningful about its geology. Yet astronomers have found that some asteroids — the broken fragments of larger ones — do hint at their backgrounds. When identified, these fragments offer a rare glimpse into the interior of asteroids. They also give astronomers a chance to learn more about the properties of their parent asteroids and the mechanism of their destruction.

The broken-asteroid story began 75 years ago, when Japanese astronomer Kiyotsugu Hirayama noted that a handful of asteroids share similar orbital properties. The members of these groups not only orbit at nearly the same distance from the Sun but also share similar orbital inclinations and eccentricities. Suspecting the asteroids within a group were somehow related to each other, Hirayama called the associations "families."

He wrote that explaining an asteroid family seems easy if you suppose that a large asteroid broke into a number of fragments, probably in a devastating collision with another large asteroid. The fragments — the children of the two parent bodies and now themselves individual asteroids — will follow their own orbits around the Sun. But as they do, each fragment "remembers" the orbit of its parent.

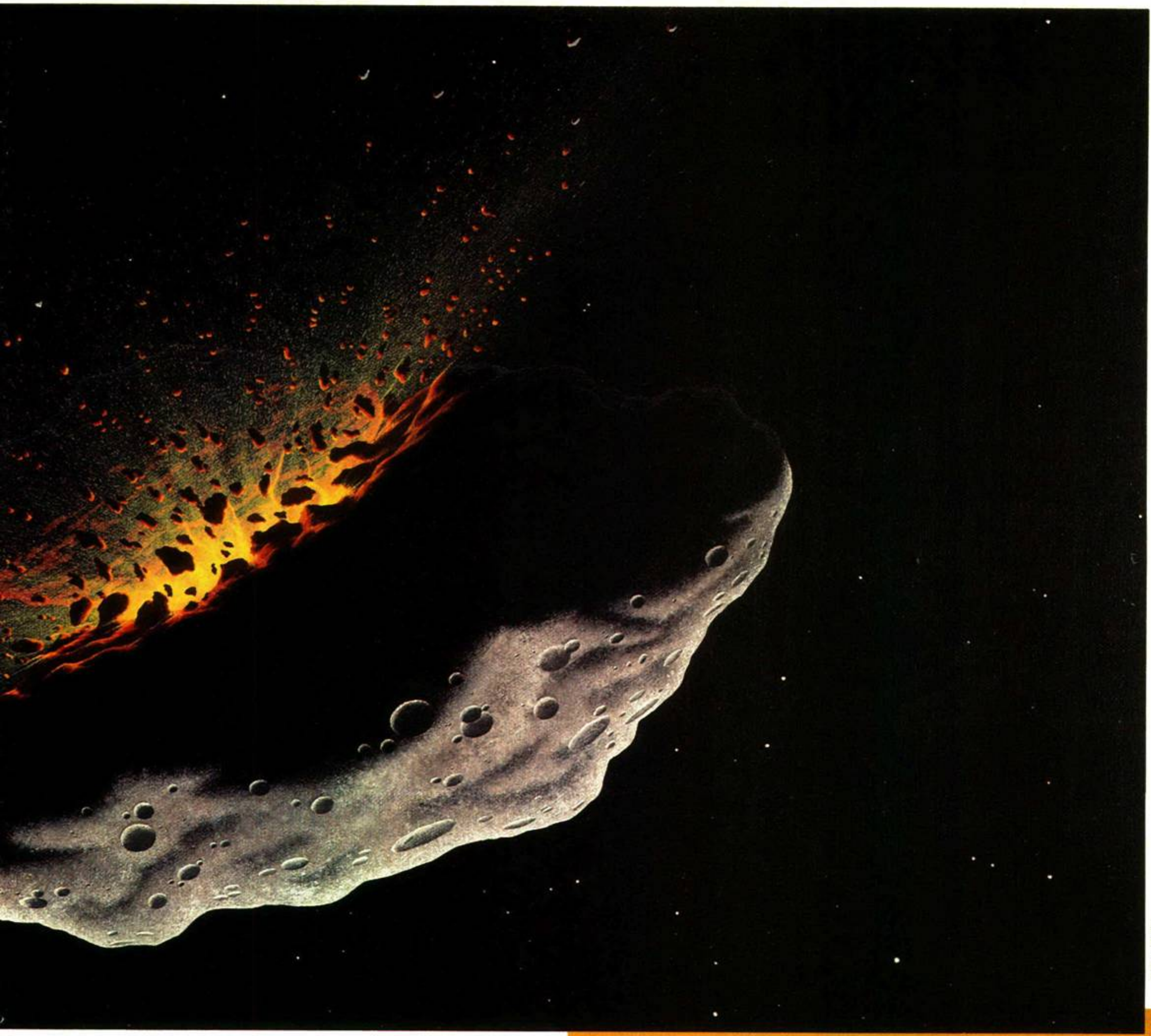
Cosmic Rock Crusher

Contrary to popular notions, the asteroid belt is a pretty empty place and collisions between major asteroids are rare. But they *do* happen . . .

Imagine a large asteroid, perhaps a couple hundred kilometers across, orbiting the Sun between Mars and Jupiter. For most of its life the asteroid has seen little more than a few crater-making impacts. Many more sand-grain-sized meteoroids drift through the belt than boulders, so most impacts have been small in scale, gardening the surface soil to a depth of several inches.

Now, however, imagine that a much larger object is approaching. Closing at more than 5 km a second, the oncoming chunk of rock — perhaps only a tenth the size of its target — slams into the asteroid.

Debris from the shattered projectile and the target asteroid is blasted away from the point of impact as an immense shock wave shudders through the asteroid. Unable to withstand the strain, the target asteroid fractures into many large pieces and countless bits of smaller debris. Fragments ranging in size from kilometers across to motes of dust promptly depart the scene of the collision at speeds up to hundreds of meters per second.



Arthur Blake

THE JARRING SLAM as two minor planets collide gives birth to an asteroid "family" with fragments sailing off on their own orbits.

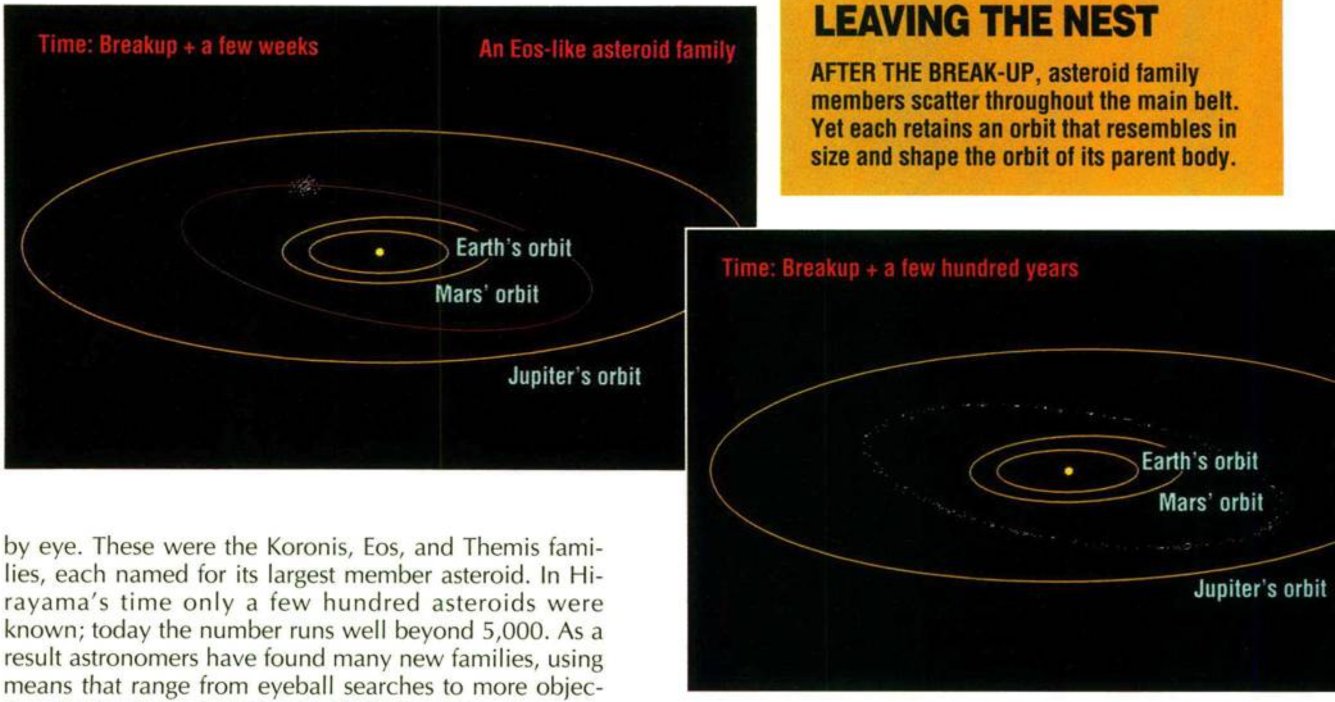
Such speeds are small, though, compared to the asteroids' orbital speeds around the Sun. This means that while the newly formed fragments assume their own orbits in the asteroid belt, the new orbits are but variations on that of the parent. Thus an asteroid family is born.

Needles in Haystacks

Rounding up family members today, however, is a big challenge because they no longer orbit the Sun in tight groups. At the beginning, each family is a little clump of debris, but this stage soon passes. After only a few hundred years, their relative speeds will spread the members of a family into a ring of sorts around the original orbit (see pages 38-39). Then over a period of a million years or so, gravitational tugs from the planets, especially Jupiter, will completely smear the orientations of the orbits around the belt. At any given moment today, individual family members may lie scattered on opposite sides of the asteroid belt.

When this happens astronomers can recognize a family only after they carefully compare the orbital elements of lots of asteroids, most of which are probably unrelated in reality. Orbital elements are the mathematical quantities that define the shape and orientation in space of an orbit. Some orientation elements can be altered by the gravity of other planets, but orbital shape is more durable. Astronomers therefore plot invariable elements against each other, looking for similarities. When they do this, they find that members of a family tend to cluster on a graph (see page 39).

Hirayama found the three most prominent families


Time: Breakup + a few weeks
An Eos-like asteroid family
Earth's orbit
Mars' orbit
Jupiter's orbit
Time: Breakup + a few hundred years
Earth's orbit
Mars' orbit
Jupiter's orbit

Dan Durda

LEAVING THE NEST

AFTER THE BREAK-UP, asteroid family members scatter throughout the main belt. Yet each retains an orbit that resembles in size and shape the orbit of its parent body.

by eye. These were the Koronis, Eos, and Themis families, each named for its largest member asteroid. In Hirayama's time only a few hundred asteroids were known; today the number runs well beyond 5,000. As a result astronomers have found many new families, using means that range from eyeball searches to more objective mathematical methods. Unfortunately, some researchers claim to be able to identify more than a hundred groupings, while others consider that only the few largest families are real.

The disagreements arise from several causes, such as different astronomers' using different starting sets of asteroids. Early family classifications included fewer asteroids; as more asteroids become known, investigators can identify the less well-populated families that went undetected previously. Second, different ways of calculating the orbital elements yield different groups. And third, different statistical ways of distinguishing family groups from the background asteroids of the main belt can produce different families also.

Probably the most extensive list of asteroid families is that of Jim Williams of the Jet Propulsion Laboratory. In his latest work, he has identified 104 families, many quite small, by examining stereoscopic plots of the asteroids' elements (see page 40). He then puts those clusters he has visually identified through a statistical test to see if they really do stand out against the background of the other asteroids.

Another list of families comes from the work of Vincenzo Zappalà and his co-workers in Italy. They use a large set of asteroids, a refined theory for deriving elements, and an objective method of looking for non-random groupings of asteroids. Zappalà and colleagues have found 21 families that they consider to be statistically reliable, most of which match fairly well those found by other astronomers.

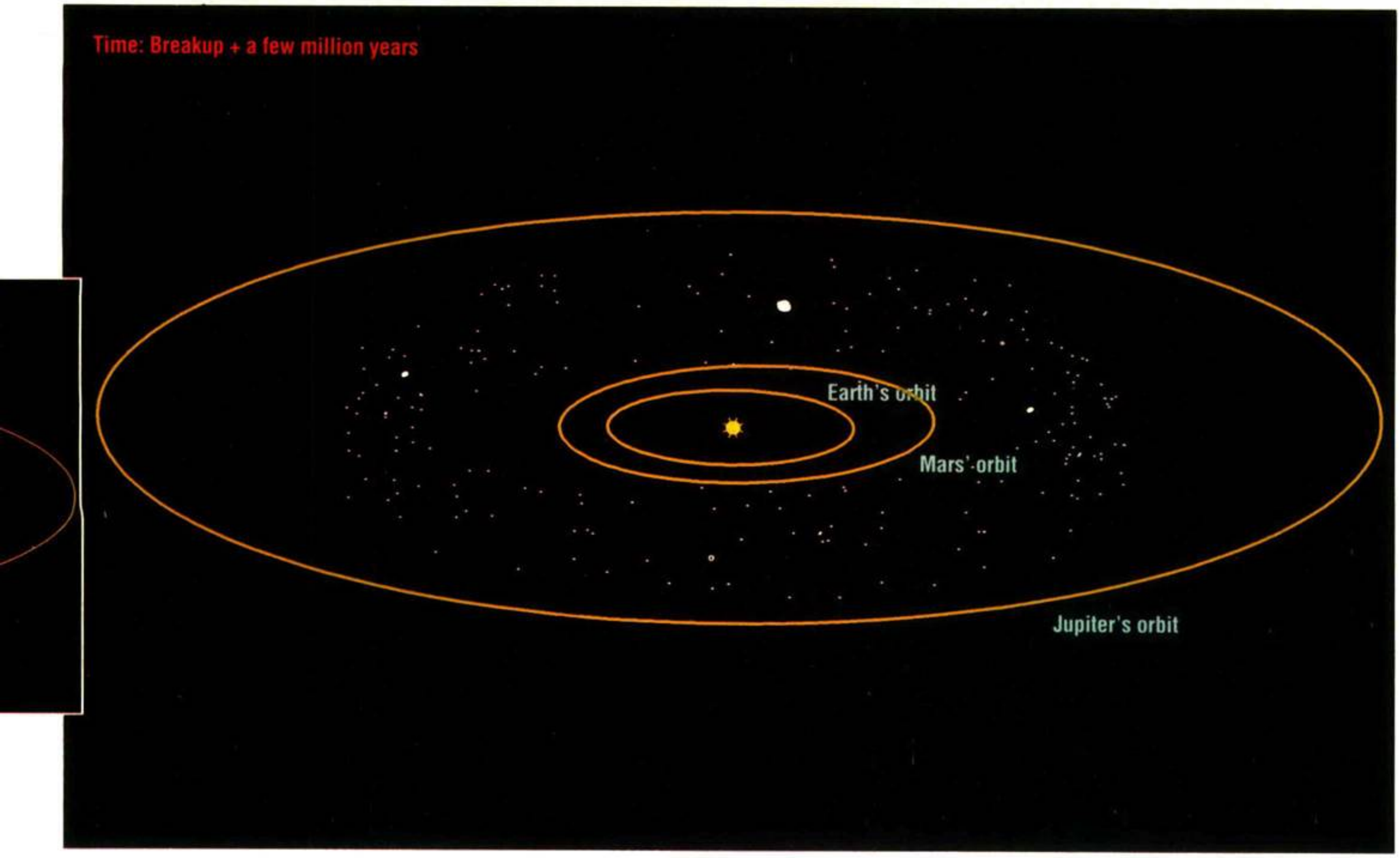
When a collision smashes a big asteroid, the debris doesn't fly off just anywhere.

Putting Humpty Together Again

Finding families is only half the battle. If families are to help scientists understand the physical nature of asteroids, then astronomers must be careful that their lists contain families that are truly the results of catastrophic collisions and not chance groupings of unrelated objects. Clearly, since there is no unanimous agreement on the number of families or on which asteroids should be included in families, it's natural to ask if *any* of the families identified by various researchers are real.

Some asteroid scientists, particularly Jeff Bell of the University of Hawaii and Clark Chapman of the Planetary Science Institute, have attempted to answer this by looking to see if the families make geological sense. They reason that if a family originates in the destruction of a single parent asteroid, scientists should be able to reassemble the various members into a geologically believable parent body. Bell and Chapman use asteroid-type classifications that are based on how asteroids appear as viewed from Earth with spectroscopes and photometers. These classifications imply certain mineralogies that can be correlated with how rocks are known to form. Let's look at some families in more detail and see how the Williams and Zappalà lists of families compare when examined in this manner.

Hirayama found the three largest families in his pioneering study in 1918. The Koronis, Eos, and Themis families together comprise the majority of family asteroids. Of the 5,000 or so numbered asteroids, more than 860 belong to families and almost 600 belong to these three large families. Not unexpectedly, the three families are virtually identical in both the



Williams and the Zappalà classifications. Moreover, all three are geologically consistent with the idea of a single-parent body since the asteroids within each family exhibit the same classification types.

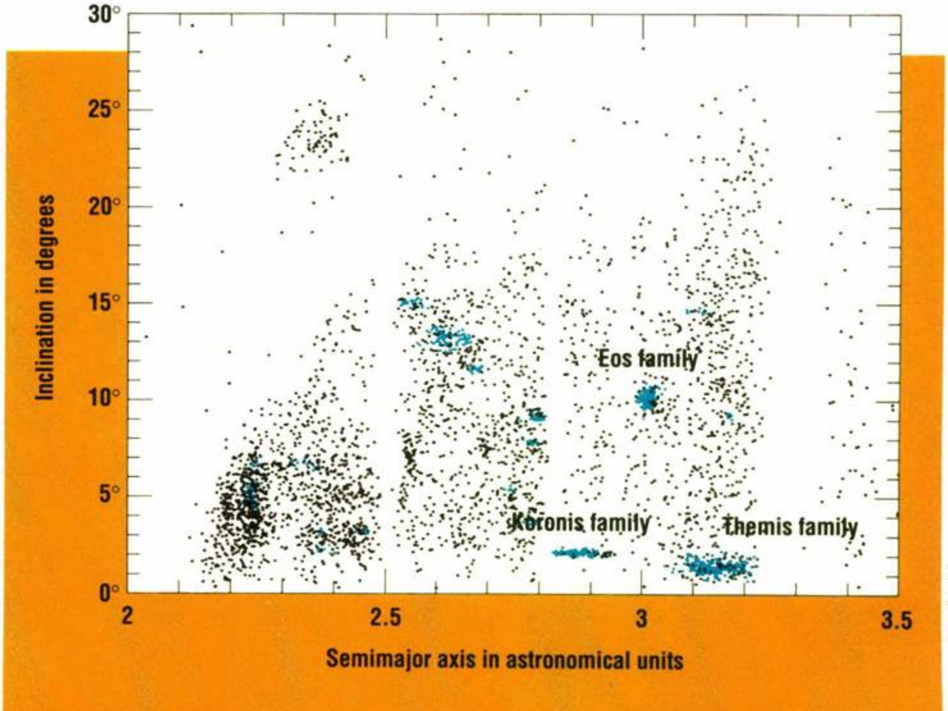
The Koronis family resulted from the destruction of a modest-sized asteroid. Koronis itself is about 40 km across and some other members of the family are almost as large. This suggests the parent body broke apart completely in the collision. Observed from Earth, the Koronis family members show large changes in brightness, indicating that many are tumbling fragments with irregular shapes. Astronomer Rick Binzel of MIT studied their rotation rates and concluded that the Koronis family may be relatively young. Its members appear not to have undergone many collisions, which would alter their shapes and spins.

Interestingly, astronomers may even be able to say something about where in its orbit the precursor asteroid was disrupted. Koronis members show very little spread in their inclinations, which hints that the parent broke apart near the high or low point in its orbital excursion from the plane of the solar system.

When astronomers plot the Eos family's orbital elements, those of the larger members all fall in a distinct core with the smaller members lying at its edges. The spread of elements within a family tells about the range of velocities with which the members were ejected when the parent fragmented. The core of a family thus represents the slow-moving, larger pieces, while the

GATHERING THE CLANS

FAMILY REUNIONS OCCUR when astronomers plot one orbital property against another. The similarities in their orbits bring family members (shown in color) together on the graph.

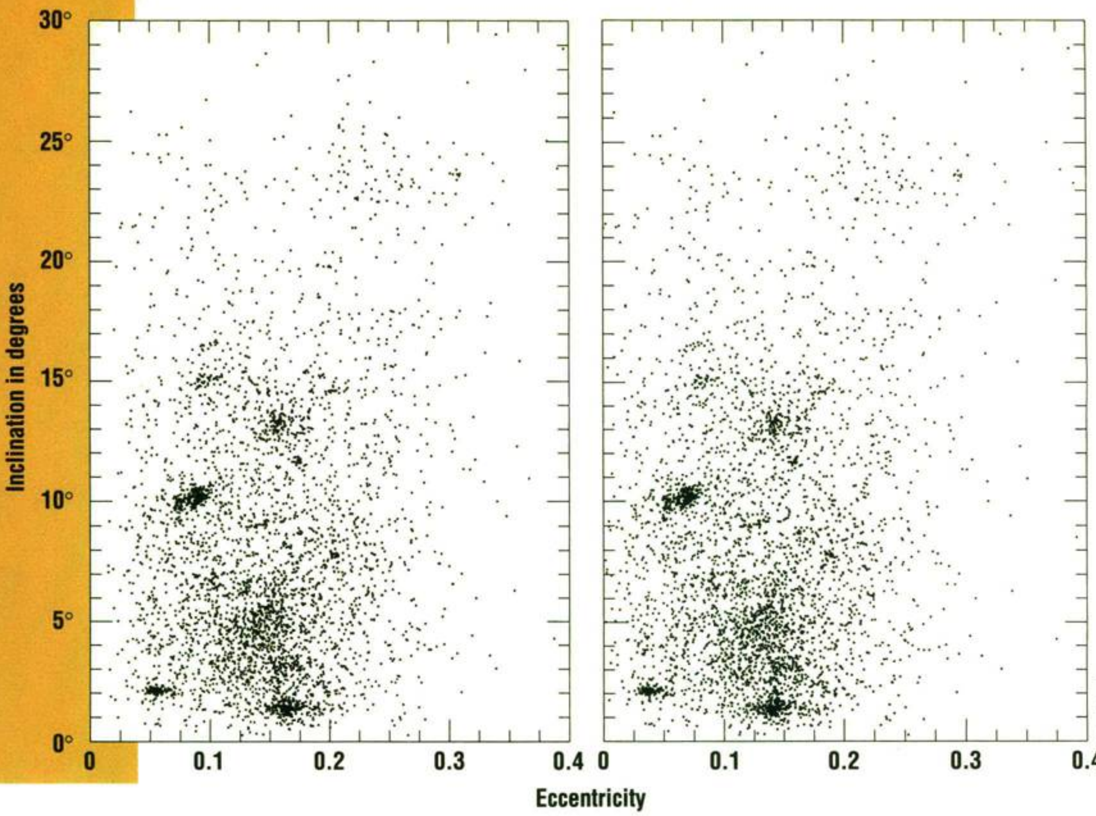


Dan Durda

BIG FAMILY OUTINGS

TO CHECK FOR FAMILIES, astronomers sometimes use 3-dimensional graphs to seek out family members. This stereo pair has semimajor axis as the dimension coming out of the page toward you.

(To see the effect without a stereo viewer, hold a piece of cardboard upright between the pair of images and illuminate both sides equally. Look down with one eye on each side of the cardboard, and relax your eyes until the two images fuse into one. Family member asteroids should appear to clump above the page.)



Dan Durda

outliers represent smaller debris ejected from the scene at higher speeds.

Like the asteroids of the Koronis family, Eos members belong to the same type and many have properties that are unique to them. The fact that the members of this family display a distinct spectral class says not only that the parent asteroid was rather homogeneous, but also that the family truly resulted from the fragmentation of a single asteroid and is not a cluster of unrelated objects.

The plot of the very large Themis family also shows a compact core surrounded by less-dense clumps. Most of the non-core members of the Themis family lie to one side of the core, which may indicate that these fragments came from one side of the parent body. Williams estimates that the parent object lost some 60 percent of its mass in the collision and that Themis itself, some 227 km across, is the intact remnant of the parent. In what might be considered an enormous cratering event, much of one hemisphere of the Themis parent was blasted into space. The remaining hemisphere blocked the debris from traveling into the other side of the sky. The less-dense clumps in the outer parts of the family may represent subsequent collisions that further broke apart some of the resulting family members. Astronomers suspect the family trees of many asteroids may show these hierarchies of fragments.

A similar event but one much smaller in scale seems to have created a tiny family found by both Williams and Zappalà. It is associated with the asteroid Vesta. This is extremely interesting since Vesta is well known for having unique spectral properties that indicate it has a basaltic crust, unlike other asteroids. However, Vesta's spectrum changes as it rotates. Vesta seems to have a hole in its crust, revealing olivine-rich rock in the lower crust and mantle below. Binzel reported that the sparse family of little asteroids associated with Vesta shares its spectrum and probably represents blocks of crustal rock excavated from the surface long ago. When a spacecraft eventually visits Vesta, astronomers expect to see at least one very large impact scar on its cratered surface.

Millions of years

after the fact,

astronomers can still

spot the runaway pieces

of an asteroid's break-up.

Merged and Blended Families?

The Zappalà and Williams lists of the big families like Koronis, Eos, and Themis largely agree, but there can be quite a bit of disagreement on smaller families.

Asteroids Nysa and Hertha have been linked in many previous family classifications. They appeared to be pieces from the destruction of a parent asteroid that melted throughout and differentiated — that is, it became stratified, with its heavy material sinking to make a core. Nysa has a diameter of about 73 km, while Hertha is 82 km across. Nysa's spectrum links it to a type of stony meteorite that astronomers think comes from the mantles of bodies that are differentiated. Hertha could be the metallic core (or part of it) of the parent asteroid.

Most recent family classifications, however, do not include a well-defined Nysa-Hertha family. For instance, neither asteroid appears among the statistically significant families of Zappalà. Williams

GASPRA COMES FROM A GROUP of minor planets that may be associated with the asteroid Flora. Judging by the extent craters have marked its surface, astronomers think Gaspra may have been a separate body for the last 200 million years.

JPL/NASA

places them into two separate, but not widely separated, smaller families. There are also a number of small, rare, and primitive asteroids associated with the Nysa group, which would be difficult to understand from a mineralogical standpoint. Jeff Bell and others have even suggested that Nysa and Hertha are interlopers in a more homogeneous family composed of primitive asteroids.

Bell examined both the Zappalà and Williams lists of asteroids and found that most of the geologically questionable Williams families do not correspond to any of the Zappalà families. Although it seems that many of the Williams families cannot derive from a single parent asteroid, most of the Zappalà families can. Bell concludes that in general the Zappalà families are closer to reality than the families identified by Williams.

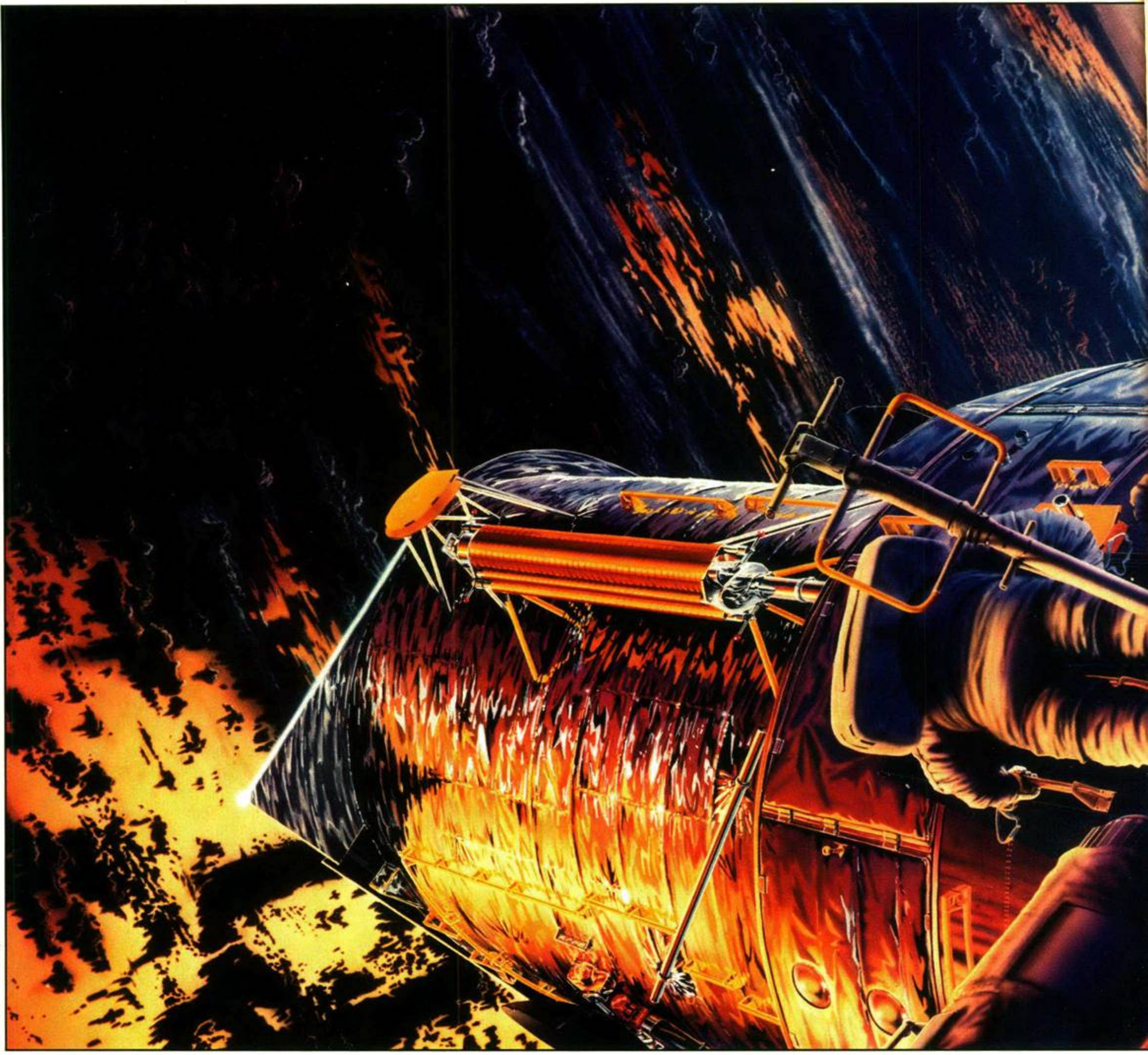
This is not to say that all the small Williams families are false. Clark Chapman notes that some of these families are distinct in composition from the background asteroids around them. This suggests that the asteroids within the families may relate to one another, even though they may not seem to make mineralogic sense at first. Williams suggests that some of his families that contain a mix of types may be examples of families that suffered several collisions over the age of the solar system. Collisions with the parent body in its early days, when impacts were more frequent, would distribute primitive material, while later impacts would excavate more geologically processed material. Thus some families might preserve a record of collisions with an evolving asteroid, and these families would then contain what appear to be discordant types.

Williams cautions that it might be better to use families to explore relationships between types of asteroids rather than vice versa. It is also wise to remember that the mineralogic interpretations of some asteroid types may not necessarily be correct. For example, the nature of the very common stony, or S-type, asteroids is still a source of debate among researchers. Planetary scientists hope that data from the Galileo encounters with Gaspra and Ida, both S-type asteroids, may help. In fact, both Gaspra and Ida are members of families: Gaspra lies in a complex cluster perhaps associated with the asteroid Flora, and Ida is a member of the Koronis family.

Clearly, astronomers will have to study these clusters of asteroids more carefully before they can understand their origin. As more and fainter asteroids are discovered and studied, missing pieces to the family puzzles will fall into place. Astronomers expect to identify many smaller families in the outer asteroid belt. The entire asteroid population, in fact, will likely display a fractal nature: families within families within families.

When researchers have gleaned from observations the physical properties of more individual members of asteroid families, they will be better able to reconstruct the parent asteroids and the circumstances of their destruction. It's a little ironic that astronomers can best bring asteroid families back together again by exploring the details surrounding how they broke up! No astronomer anticipates running the video of the asteroid belt in reverse right back to the beginning. But tracking down asteroid families is proving to be a powerful way to unlock some closed portions of the solar system's history. □

Dan Durda is an astronomer at the University of Florida who studies the collisional evolution of asteroids. He is also investigating how much solar system dust comes from asteroid collisions.



Scott Kahler/Ball Corporation

THE HUBBLE SPACE TELESCOPE

HOW WE'LL FIX HUBBLE

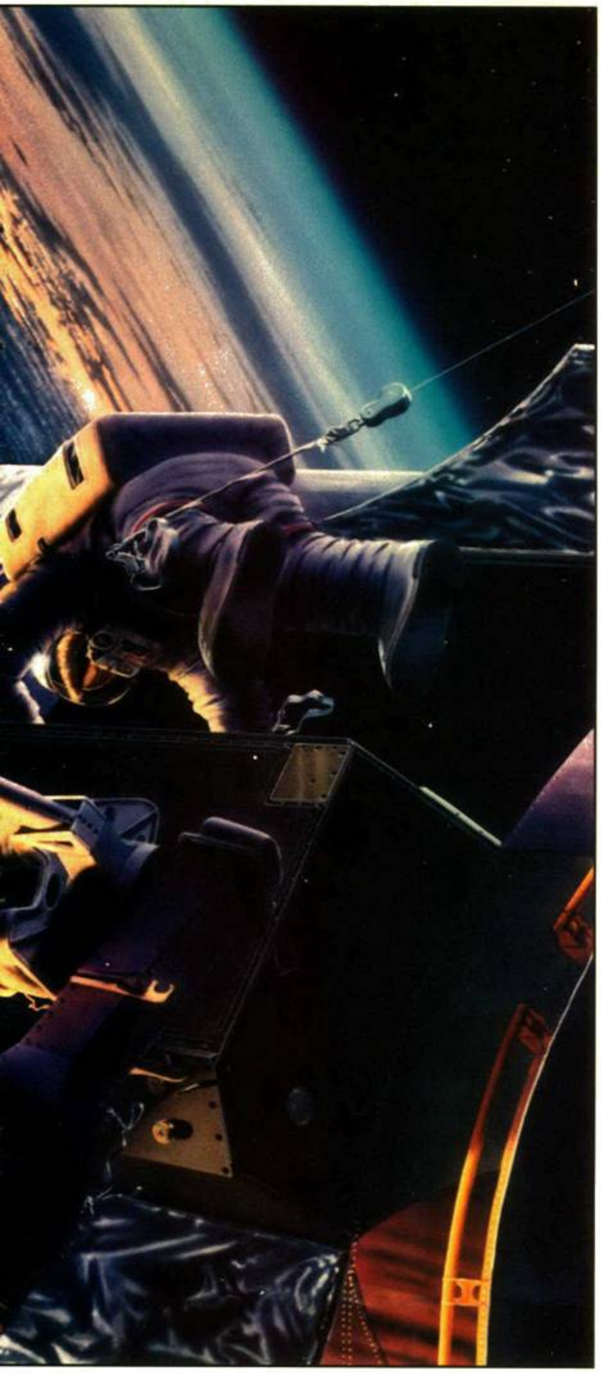
A year from now, astronauts will install an ingenious set of corrective eyeglasses into the Hubble Space Telescope to give it razor-sharp vision.

by Greg Davidson

It will take two astronauts three full working days, performing the most demanding series of spacewalks ever attempted by NASA. But the result should be a Hubble Space Telescope restored nearly to its original potential, able to see to the edge of the universe.

To fix Hubble's eyesight, astronauts will install two major pieces of equipment: a new camera system called the Wide Field and Planetary Camera II and a unique set of optics called COSTAR, the Corrective Optics Space Telescope Axial Replacement. Both are part of an ambitious mission now set for late 1993 or early 1994.

The Hubble Space Telescope's optical problems have been well publicized. Shortly after



FIXING HUBBLE will take two astronauts a total of 18 hours of intense work in the payload bay of the shuttle.

Hubble's launch on April 24, 1990, astronomers and engineers began to put Hubble through its paces. They discovered two major problems: images that wouldn't focus as well as they should and images that jittered briefly when Hubble flew into sunlight and back into darkness during every orbit.

The jitter was soon pinned down to the two solar panels that extend like wings from the side of Hubble. These supply the telescope with power. Every 90 minutes when Hubble orbits from night into day the panels heat up from –150° F to 200°. Half an orbit later the telescope enters night and the panels cool. The abrupt changes in temperature cause the panels to "flap," making Hubble jitter twice each orbit. The jitter is slight but the unwanted motion smears images, makes it difficult to lock onto targets, and cuts into the amount of observing time Hubble can provide.

Engineers developed special software that commands Hubble's pointing system to compensate for the jitter automatically and reduce its effects. But the real fix requires replacing the solar panels with a set that will remain stable despite the temperature changes. Installing new panels is an important but not unexpected part of the repair mission. Exposed to radiation in space, solar cells eventually drop in power output, so NASA had always planned to change the panels at some point anyway.

In fact, from the beginning of the Hubble program in the late 1970s, NASA planned for space shuttle astronauts to repair and upgrade the orbiting observatory. The task of the first repair mission that was never expected, however, is the fix of the telescope's optics.

Out by That Much

Hubble is a Cassegrain reflecting telescope. In this system, light enters the front of the tube and travels to the back where it hits a large primary mirror. In Hubble's case, the primary is 2.4 meters across. The concave primary mirror reflects the light up to a small convex secondary mirror. The secondary then bounces the light back down the tube and through a hole in the primary. On Hubble, the various instruments cluster around the point where the light reaches focus at the back of the telescope behind the primary.

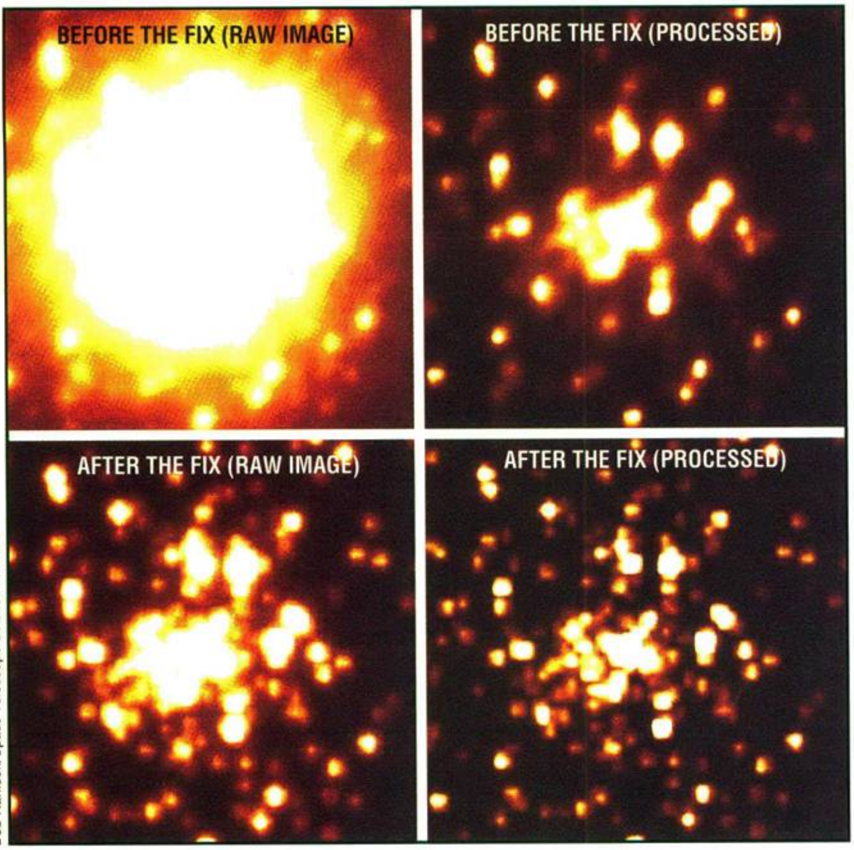
Engineers have diagnosed Hubble's optical flaw as spherical aberration: starlight hitting the outer rim of the primary mirror comes to a focus farther back than light that passes closer to the center of the primary. The result? There is no single focus position that yields the sharp images Hubble was designed to provide.

By analyzing the appearance of the star images, engineers determined that the fault lies in the concave primary mirror. The mirror has the wrong curvature, although at the mirror's edge where the error is greatest, the mirror is too flat by a mere two microns, or one five-hundredth of a millimeter.

How We Won't Fix Hubble

Beginning in the autumn of 1990, NASA brought together a team of scientists and engineers at the Space Telescope Science Institute to look for ways to repair Hubble's optics. This strategy panel came up with a list of twenty-eight possible ways to fix Hubble. Among them were

- An inflatable ring around the bottom edge


BEFORE THE FIX (RAW IMAGE)
BEFORE THE FIX (PROCESSED)
AFTER THE FIX (RAW IMAGE)
AFTER THE FIX (PROCESSED)

Bob Hanisch/Space Telescope Science Institute

HUBBLE'S NEW OPTICS will sharpen its vision. At top left is a simulation of how a star cluster looks now through Hubble's eyes. Computer processing (top right) can recover much of the lost detail, at least on bright targets in uncluttered fields. After the corrective optics are installed, the same cluster should look like the image at lower left, even without image enhancement. With computer processing (lower right), details appear sharper still.

of the primary to literally bend the mirror into shape.

- Heaters around the rim of the primary, also to warp the mirror.
- A large corrector lens over the front of the telescope.
- A new secondary mirror designed to correct the spherical aberration.
- Corrector lenses in front of each instrument.

The panel judged these and other solutions too difficult to test or install. Many of the proposals would also introduce unwanted optical side effects that might be worse than the original problem. For a week or two in late 1990 the team even considered having astronauts place an aperture mask over the front of the telescope tube, a relatively simple fix that could have been flown on an emergency shuttle mission as early as January 1991. They discarded this option because it would have blocked too much light.

Eyeglasses for Hubble

The simplest way to correct the aberration is to place a corrective lens or mirror at the focus. The corrective optic must have a surface with an equal but opposite amount of distortion built into it — essentially an eyeglass for Hubble. In practice, however, mirrors will be used instead of lenses because lenses have problems focusing all colors to the same point. Lenses also absorb the ultraviolet light that some of Hubble's instruments are designed to study.

Although the principle is simple, implementing the idea is no easy task. Hubble's primary mirror is 2.4 meters across; the tiny corrective mirrors each have to be about the size of a quarter. The mirrors have to be so smooth that no bumps on their surfaces can be higher than 10 angstroms, about $^1/_{500}$ the size of a wavelength of green light.

Because the corrective mirrors are so critical, NASA had several potential manufacturers bid on the job. Three of the four competitors were large and highly skilled optics houses. The fourth, and the eventual winner, was a small California company with only 81 employees, Tinsley Laboratories. Tinsley specializes in off-axis aspheric optics for commercial and military customers, the type required for Hubble.

Taking no chances, Tinsley used three independent tests to check the accuracy of the now-completed mirrors: two interferometry tests and a check using a profilometer, a machine that touches the corrective mirrors with a tiny ball, measuring them with an accuracy of up to a millionth of an inch. Still more tests were performed by Ball Corporation and the Jet Propulsion Laboratory and then verified by the Goddard Space Flight Center, the European Space Agency, and the Space Telescope Science Institute.

Since the tolerances on the mirrors are so tight, astronauts cannot insert the corrective optics inside each of Hubble's instruments during a servicing mission with the required precision. Instead, the optics from Tinsley will be built into a new Wide Field and Planetary Camera being built by the Jet Propulsion Laboratory and into a separate mechanical device being manufactured by Ball Corporation, the COSTAR apparatus.

Why COSTAR?

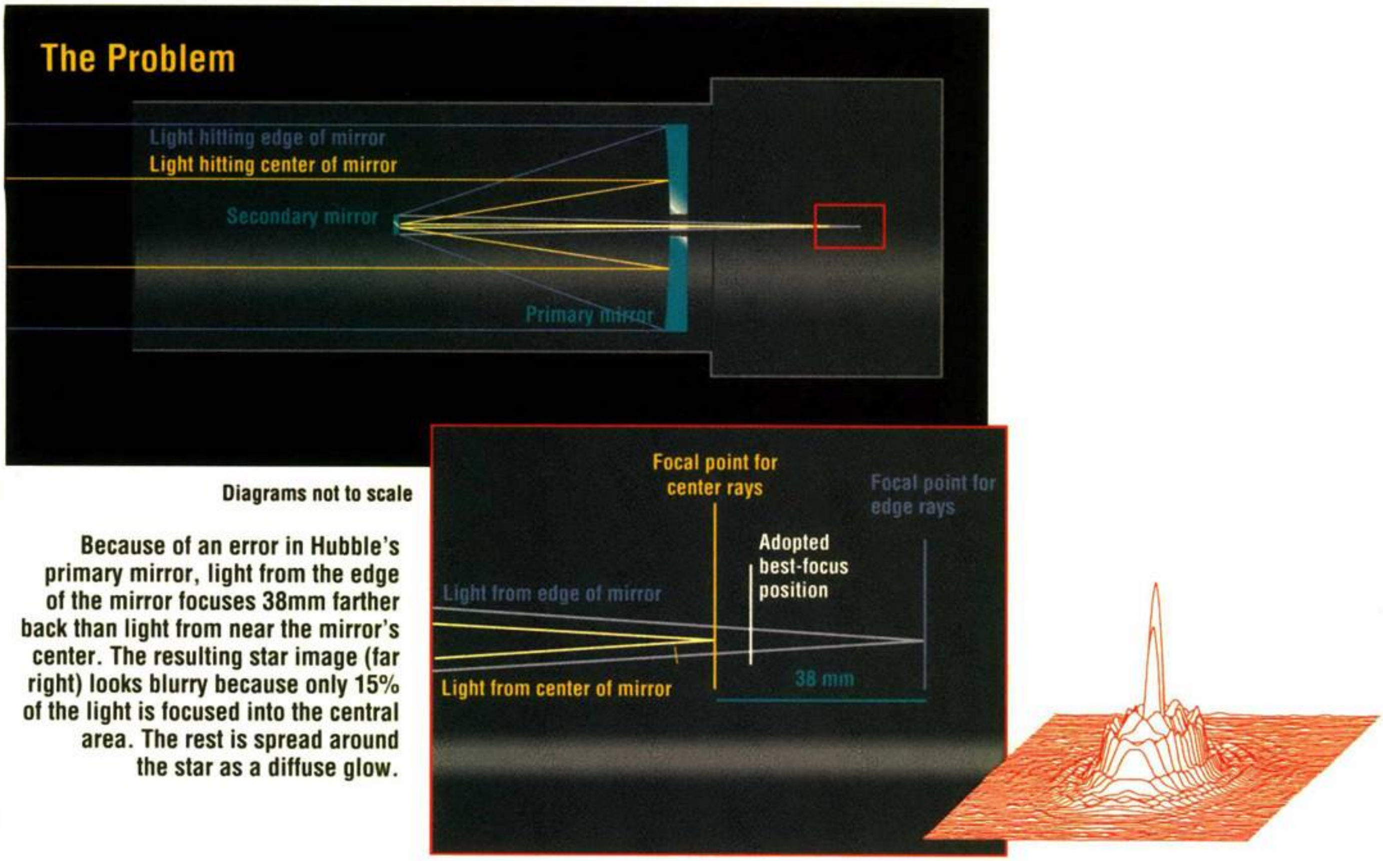
Hubble currently has five main science instruments. Four are phone booth-sized boxes clustered behind the telescope's focus. These are the "axial" instruments. Each can "see" part of the telescope's focal plane. A fifth instrument, the Wide Field and Planetary Camera, sits in a slot on one side of the telescope. It uses a flat mirror to deflect light at right angles from the focal plane into the camera.

Ideally, any optical fix should correct the light going into all five instruments. The COSTAR design, which was the unanimous recommendation of the strategy panel, provides a correction for three axial instruments that is color- and coma-free.

To install COSTAR, astronauts will remove one of the four axial instruments, the High Speed Photometer, and put COSTAR in its place. The photometer will be returned to Earth.

Although COSTAR replaces the photometer, its advantage is that it is a self-contained unit that is easy to install precisely in orbit. As the report recommending COSTAR put it: "The

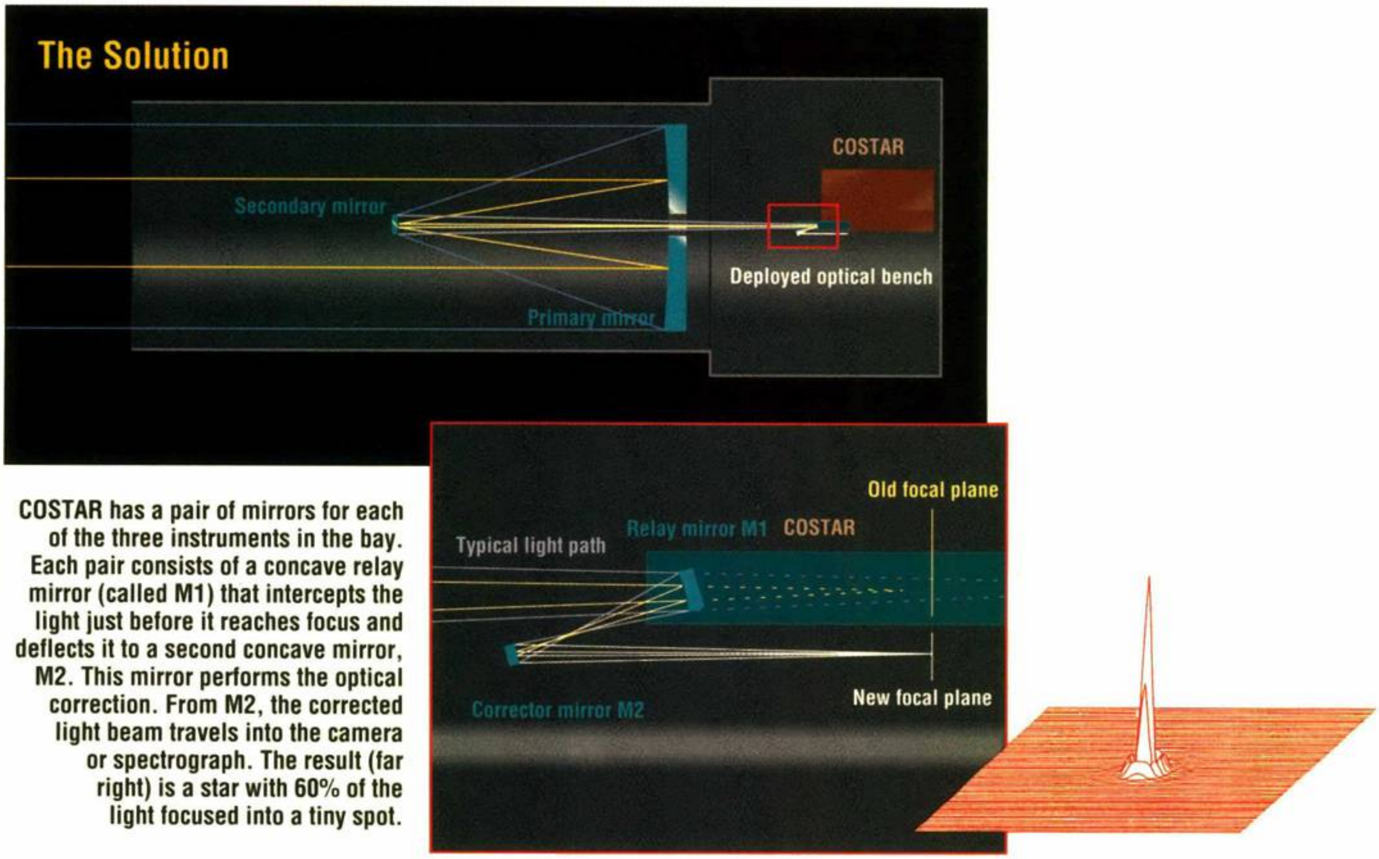
The Problem


Light hitting edge of mirror
Light hitting center of mirror
Secondary mirror
Primary mirror
Focal point for center rays
Focal point for edge rays
Adopted best-focus position
Light from edge of mirror
Light from center of mirror
38 mm

Diagrams not to scale

Because of an error in Hubble's primary mirror, light from the edge of the mirror focuses 38mm farther back than light from near the mirror's center. The resulting star image (far right) looks blurry because only 15% of the light is focused into the central area. The rest is spread around the star as a diffuse glow.

The Solution

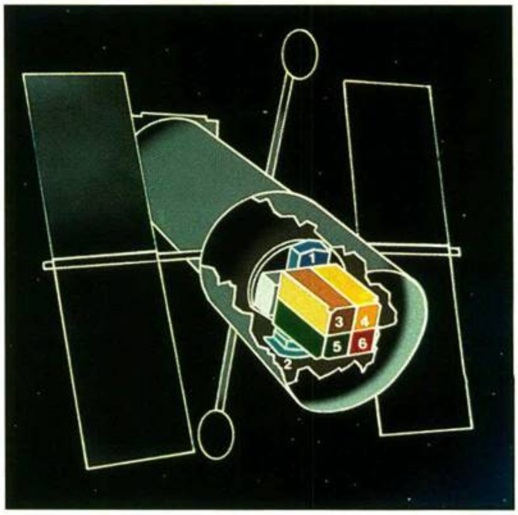

Secondary mirror
Primary mirror
COSTAR
Deployed optical bench
Old focal plane
Relay mirror M1
COSTAR
Typical light path
Corrector mirror M2
New focal plane

COSTAR has a pair of mirrors for each of the three instruments in the bay. Each pair consists of a concave relay mirror (called M1) that intercepts the light just before it reaches focus and deflects it to a second concave mirror, M2. This mirror performs the optical correction. From M2, the corrected light beam travels into the camera or spectrograph. The result (far right) is a star with 60% of the light focused into a tiny spot.

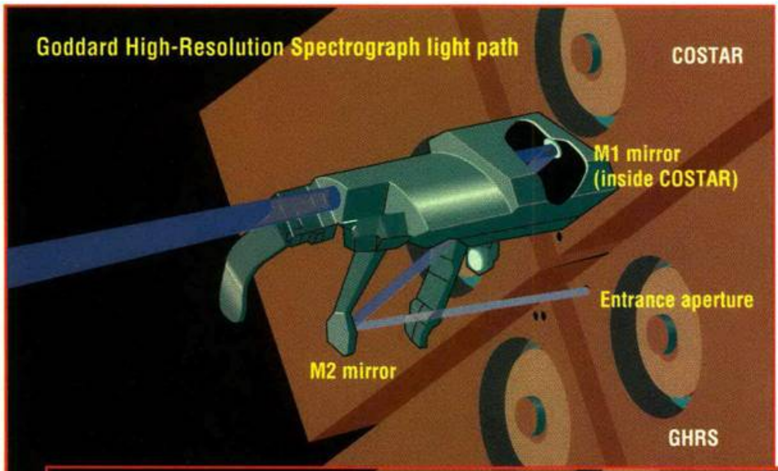
ASTRONOMY: Thomas L. Hunt

IT'S ALL DONE WITH MIRRORS

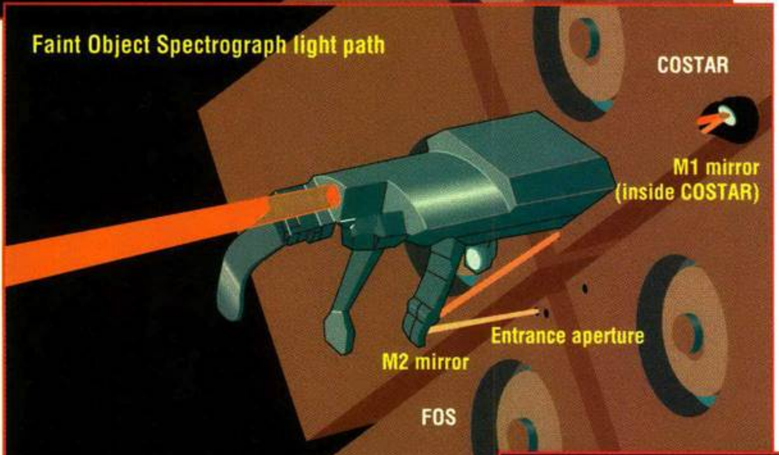
HUBBLE'S INSTRUMENTS ARE CLUSTERED at the back of the telescope. The Wide Field and Planetary Camera (labeled #2) is located to one side of the instrument bay. The four "axial" instruments are located in the center of the bay. These include the Goddard High-Resolution Spectrograph (#3), the High Speed Photometer (#4), the Faint Object Spectrograph (#5), and the Faint Object Camera (#6). The instrument labeled #1 is one of three Fine Guidance Sensors that help aim Hubble. COSTAR will replace the High Speed Photometer and insert corrective mirrors into the light paths for the other three axial instruments.



NASA/Space Telescope Science Institute


Goddard High-Resolution Spectrograph light path
COSTAR
M1 mirror (inside COSTAR)
Entrance aperture
M2 mirror
GHRS

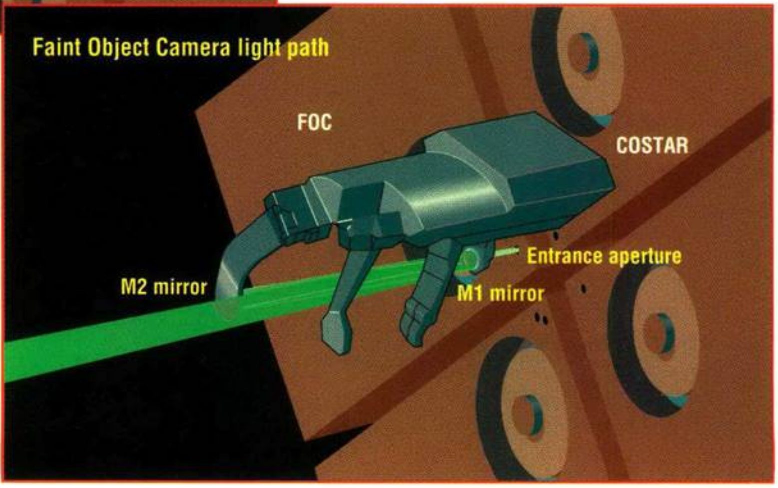
THE GODDARD HIGH-RESOLUTION SPECTROGRAPH can record very detailed spectra of stars and galaxies in ultraviolet light, a part of the spectrum that cannot penetrate Earth's atmosphere. After COSTAR, the instrument will be able to record spectra of objects fainter than it can now.

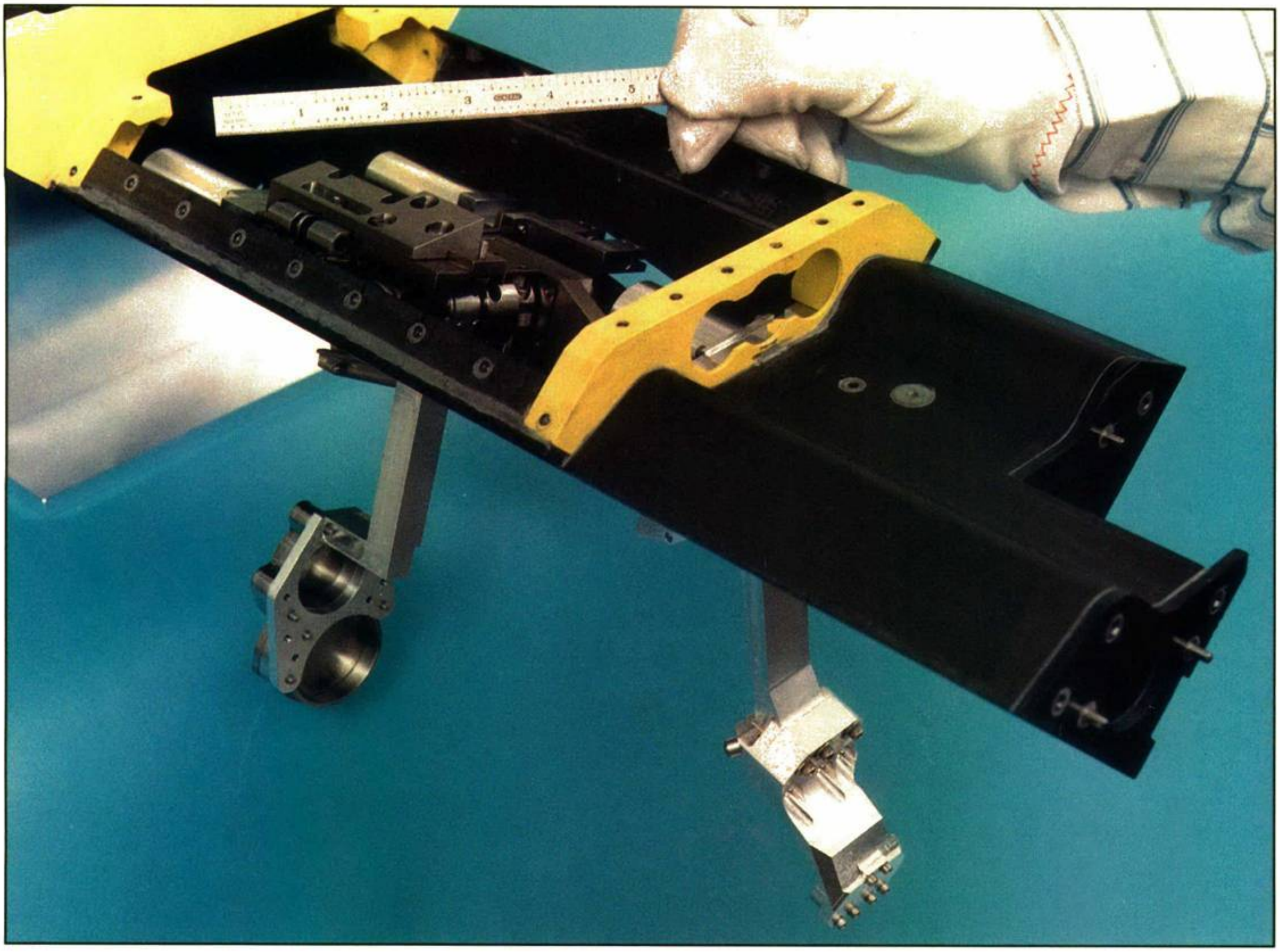

Faint Object Spectrograph light path
COSTAR
M1 mirror (inside COSTAR)
Entrance aperture
M2 mirror
FOS

THE FAINT OBJECT SPECTROGRAPH complements the Goddard High-Resolution Spectrograph (GHRS) by taking spectra of objects too faint to be seen by the GHRS. It can also take spectra in both visible and ultraviolet light. COSTAR will make it possible for this instrument to detect objects nearly as faint as those it was originally intended to record.

ASTRONOMY: Thomas L. Hunt after Ball Corporation

THE FAINT OBJECT CAMERA was built by the European Space Agency. Its task of photographing very faint objects at high resolution has been hampered by Hubble's fuzzy images. After COSTAR, the Faint Object Camera will have most of its original capability restored.


Faint Object Camera light path
FOC
COSTAR
Entrance aperture
M2 mirror
M1 mirror



Ball Corporation

great beauty of COSTAR is that it fits seamlessly into both the design of the Hubble spacecraft and the philosophy of the HST program. Physically, COSTAR is like all the axial instruments, which are designed to be switched in and out of the telescope." In fact, using water tank simulations, astronauts have practiced removing and installing instruments from Hubble's axial bays for several years.

Once in place, COSTAR will improve the performance of the three remaining axial instruments: the Faint Object Camera (FOC), the Faint Object Spectrograph (FOS), and the Goddard High-Resolution Spectrograph (GHRS).

To provide the correction for each instrument, a mechanical arm will extend from an opening in COSTAR near the central axis of the telescope. The arm contains several pairs of mirrors. Relatively simple non-correcting mirrors intercept the aberrated beams of light entering COSTAR's quadrant of the instrument bay and reflect them back toward the front of the telescope. There, small fingers swing out from the arm. Corrective mirrors on these fingers then bounce corrected light into the instruments, while the backs of these fingers prevent aberrated beams of light from entering the instruments.

COSTAR will make it possible for Hubble's two spectrographs to take spectra of targets that are in crowded fields (for example, analyzing the area close to suspected black holes at the centers of galaxies). In addition, the spectrographs will be able to obtain spectra for some targets as much as four times faster than is currently possible, allowing astronomers to make more observations. COSTAR will also restore the Faint Object Camera's ability to take high-resolution images of the very faintest objects, enabling the camera to see to the farthest reaches of the universe with the highest possible resolution.

A New "Wif-Pik"

What about correcting the fifth instrument, the Wide Field and Planetary Camera? Usually called WF/PC (pronounced wif-pik), this is the camera responsible for Hubble's striking images of Mars, Jupiter, and Saturn, among many other achievements. Because WF/PC lies in front of the axial instruments, COSTAR's optics are not physically able to reach WF/PC's light

THE WORKING END OF COSTAR, seen here under construction, consists of an extendable arm housing several fingers that will flip down into the light path after COSTAR is in place. The critical corrector mirrors are fastened to the ends of these fingers.

HUBBLE'S FIX-IT LIST

Task	Result
✓ Install COSTAR	Improves Faint Object Camera Improves High-Resolution Spectrograph Improves Faint Object Spectrograph but eliminates High Speed Photometer
✓ Install WF/PC II	Upgrades Wide Field and Planetary Camera
✓ Replace solar panels	Eliminates pointing jitter
✓ Replace failed gyroscopes	Restores redundancy in pointing system
✓ Install cable modification for High-Res. Spectrograph	Restores redundancy in signal paths in GHRS
✓ Perform other minor fixes	Fixes items that may fail in next year

path. Instead, astronauts will replace the camera with an entirely new instrument, the Wide Field and Planetary Camera II.

This is not so drastic as it sounds. At the time of Hubble's launch, the WF/PC II was already under development at the Jet Propulsion Laboratory as part of the long-term upgrade plans for Hubble's instruments. After discovering the spherical aberration, the Hubble team immediately started to work on corrective optics that would fit into the original WF/PC II design.

The designers soon realized that placement of the corrective optics inside WF/PC II would be critical. If a corrective mirror was off-center by more than 1 percent, much of the improvement could be lost. Therefore, WF/PC II's built-in corrector mirrors will be precisely aligned by remote control after the new camera is installed.

WF/PC II will also provide better results than originally planned. Ultraviolet performance will be enhanced and the camera's sensitivity will be improved by using new Charged-Coupled Devices (CCDs) for the camera detectors.

A Complex Mission

Installing COSTAR, the new Wide Field and Planetary Camera, and the new solar panels will be demanding. In late 1993 or early 1994, the shuttle with a crew of seven will rendezvous with Hubble a day and a half after launch. The astronauts will grab Hubble with the shuttle's mechanical arm and then secure the 43-foot-long telescope in an upright position in the cargo bay. Working in pairs on alternating days, four astronauts will take turns conducting the repairs over three days, with a six-hour shift each day.

Unlike the Intelsat spacecraft, which took days to secure, Hubble was designed to be serviced in orbit. The telescope has special grapple fixtures and 76 handholds. Hubble is also precisely stabilized in all three axes, so unlike Intelsat if Hubble is bumped during handling, the spacecraft will automatically compensate and restore its orientation.

In between shifts, ground controllers will run rudimentary tests on the newly installed equipment. Astronomers would love to be able to take images with Hubble to be sure everything is working before the shuttle departs, but for several reasons this isn't possible. First, the aperture door over the front of the telescope must be kept closed during servicing to protect the ultraclean mirror from contamination from the shuttle. Second, there is a risk from contamination for the first few weeks after the shuttle departs until the moisture and gases carried inside the new hardware brought from Earth completely evaporate into the vacuum of space.

In addition to replacing the instruments and the solar panels, astronauts will perform other routine maintenance. Two of Hubble's six stabilizing gyroscopes have failed. Three gyros are required to track changes in Hubble's position in the three directions of pitch, yaw, and roll. While the gyro system is operating fine now, two of three redundant gyros have been lost and two more of the remaining gyros could fail in the same manner. The current plan is to replace each of the assemblies holding a failed gyro as well as replace a gyro electronics control unit to increase redundancy.

After the Mission

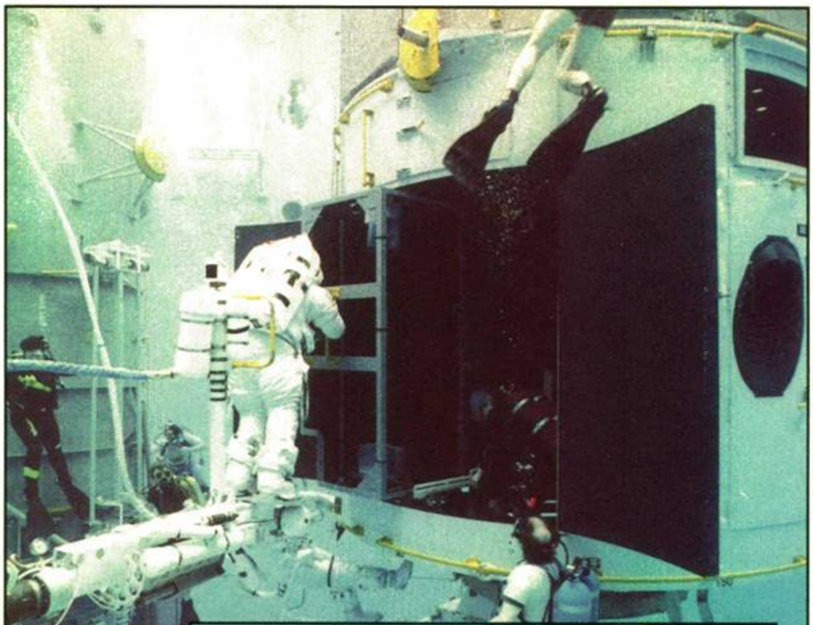
Barring unforeseen difficulties, the flow of corrected data should begin two months after the servicing mission. However, first light for the corrective optics, even if they are built and installed perfectly, will be a bit blurry until they have been aligned and focused in orbit.

First, engineers will take a week of observations with the three axial instruments before deploying the COSTAR optics. They will use this data to check for unexpected changes in these instruments caused by the servicing activity itself. Then the corrective optics will be flipped into place by remote control, but not for all three instruments at first. At least one instrument will continue to perform regular science observations during the checkout period. This will keep Hubble productive while the optical experts focus and align the COSTAR and WF/PC II mirrors.

The complete checkout could take six to eight months. But at the end of the process, the Hubble Space Telescope should be capable of doing all the science it was originally intended to do — detecting young and primeval galaxies, looking for black holes, measuring the age and expansion rate of the universe, and much more.

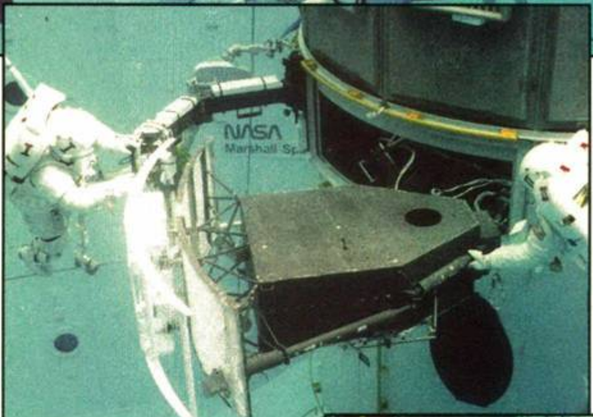
However, it is ironic that astronomers' success to date in eliminating the effects of Hubble's spherical aberration through computer processing may make it difficult to show clear-cut improvements in "before" and "after" images of some classes of objects. For images of bright objects in an uncluttered field, such as

FIXING HUBBLE will require the most ambitious shuttle mission yet. To simulate zero gravity, astronauts train for the series of tasks in an underwater tank at NASA's Marshall Space Flight Center in Huntsville, Alabama.

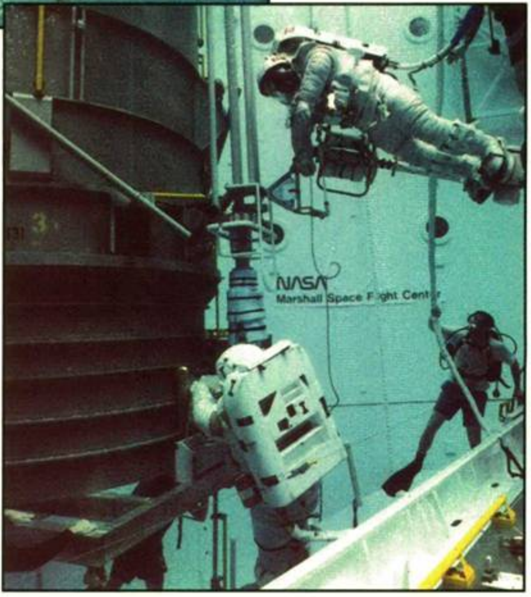


STEP 1: Astronauts remove the High-Speed Photometer from the instrument bay and install the new COSTAR box in its place to sharpen the image entering Hubble's other three axial instruments.

Photos by NASA/Marshall Space Flight Center



STEP 2: Then they remove the old Wide-Field/Planetary Camera and install the new WF/PC II, with its own set of built-in corrective optics, in its place.


NASA
Marshall Space F ght Cent

STEP 3: Finally, astronauts remove the old solar panels and replace them with a new pair that won't jitter on every orbit.

Hubble's famous images of the storms on Saturn, the processed photos appear diffraction limited. In other words, these pictures are nearly as good as the physics of light will allow even if the mirror were perfect.

More Improvements on the Way

From its inception back in the 1970s, the Hubble Space Telescope was designed to be a different type of mission for NASA — a long-lived observatory in space. To accomplish this goal and to protect the investment in Hubble against equipment failures, NASA had always planned regular shuttle servicing missions. The installation of the new Wide Field and Planetary Camera is just the first of several upgrades planned for Hubble.

In March 1997, astronauts will install two more second-generation instruments during the second Hubble servicing mission: the Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera (NIC). These will replace the Goddard High-Resolution Spectrograph and Faint Object Spectrograph. Both new instruments will contain their own built-in corrector optics, leaving COSTAR to function only for the original Faint Object Camera.

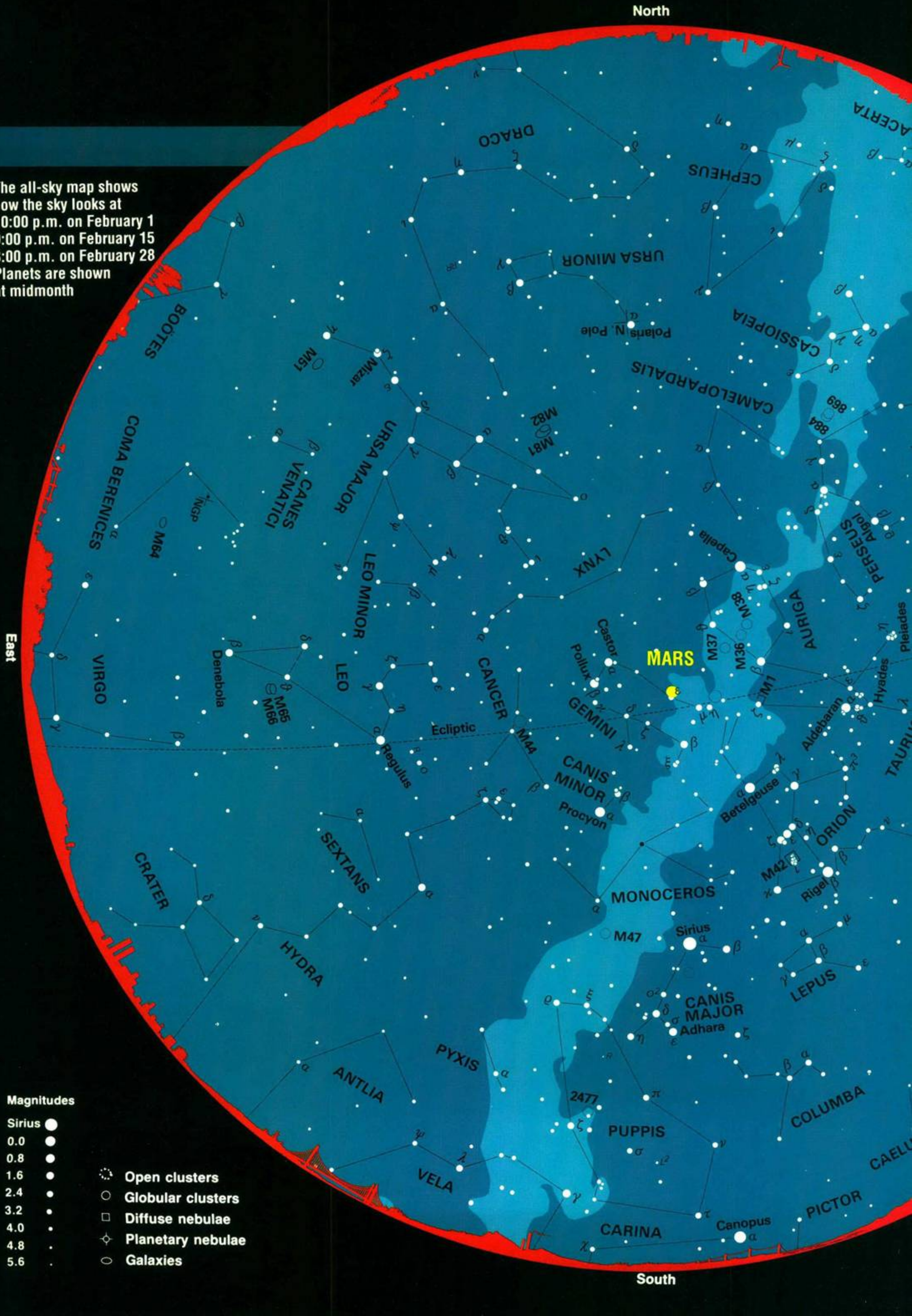
Still further upgrades are planned after 1997. Astronomers at the Space Telescope Science Institute are looking at advanced instruments to give Hubble unique capabilities for the next decade. One idea under investigation is to reuse elements of the High Speed Photometer with several new detectors that could be developed through small-scale university efforts.

The Hubble Space Telescope has a very long life ahead of it. Only a fraction of its potential has yet been seen. Unfortunately, a long time can elapse between when data are taken and when discoveries are made and announced. Unlike the Voyager observations of the outer planets, Space Telescope observations are not made public as soon as they are received. The image processing alone can take several weeks. Scientists also have proprietary rights to their data for a year. Consequently, the discoveries we have seen to date are typically made public about a year after the observation is taken. Even the head of NASA does not see the data until the scientist releases it.

Although Hubble was launched in April 1990, fulltime science operations didn't begin until January 1992. It won't be until this year that we will see evidence of the full capacity of the Space Telescope with its uncorrected optics. Similarly, the results of the tremendous improvements made on the first servicing mission won't become apparent until 1995. Nevertheless, Hubble's first servicing mission will be a milestone in the operation of the telescope, one that will allow Hubble to make even greater discoveries about our universe well into the 21st century. ☐

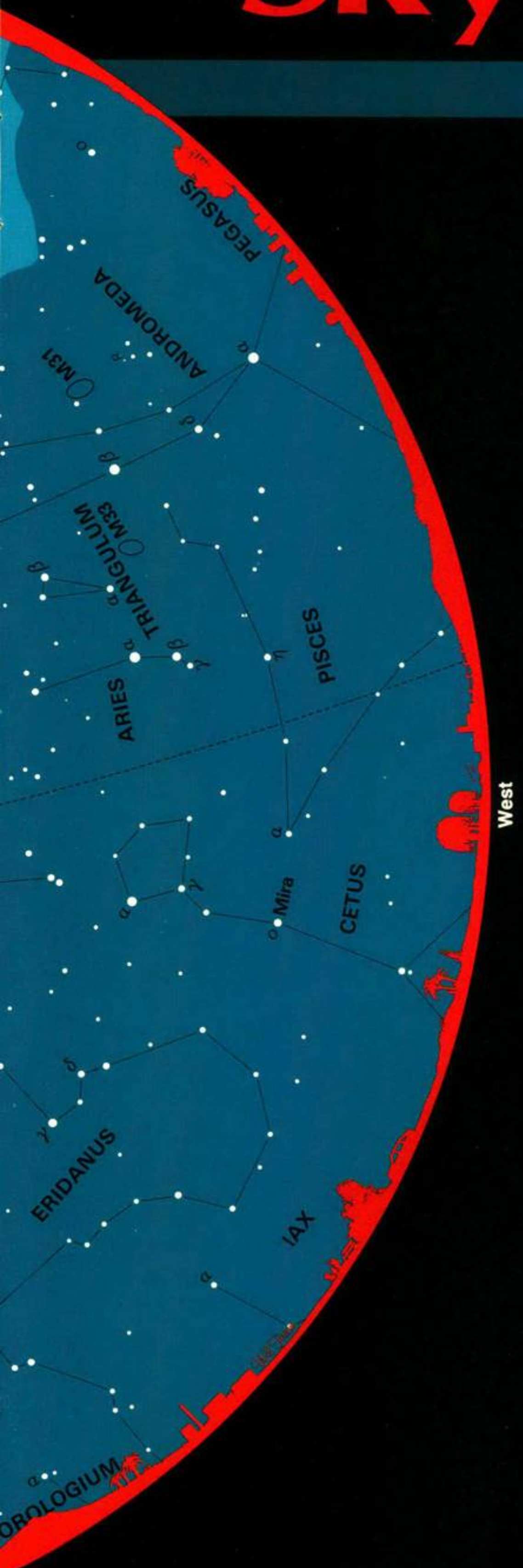
Greg Davidson is Program Manager at NASA for the Hubble Instrument Development team.

The all-sky map shows how the sky looks at
10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 28
Planets are shown at midmonth


North
South
East
DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris N. Pole
CASSIOPEIA
CAMELOPARDALIS
BOÖTES
M51
Mizar
M82
M81
URSA MAJOR
CANES VENATICI
COMA BERENICES
NGP
M64
LEO MINOR
LYNX
Capella
PERSEUS
Algol
869
884
AURIGA
M38
M37
M36
Pleiades
MARS
Castor
Pollux
GEMINI
M1
Hyades
Aldebaran
TAURUS
VIRGO
Denebola
M65
M66
LEO
CANCER
Ecliptic
Regulus
M44
CANIS MINOR
Procyon
Betelgeuse
ORION
M42
Rigel
SEXTANS
CRATER
MONOCEROS
M47
Sirius
HYDRA
LEPUS
CANIS MAJOR
Adhara
PYXIS
ANTLIA
2477
PUPPIS
COLUMBA
VELA
CARINA
Canopus
PICTOR
CAELUM
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

February 1993



VENUS SHINES BRILLIANTLY

Venus dominates the western sky after sunset this month, appearing high in the twilight glow and at its brightest for 1993. Greatest brilliancy comes on February 24, when our neighboring planet shines at magnitude –4.6.

MERCURY AT ITS BEST

This month the innermost planet puts in its best evening appearance of the year for Northern Hemisphere observers. At greatest elongation on February 21, Mercury shines brightly (at magnitude –0.4) and appears about 20° below Venus in the western twilight sky.

MARS BRIGHT IN THE EVENING

The bright ruddy object visible high in the east as evening twilight fades is none other than the planet Mars. Shining at magnitude –0.5, Mars is conspicuous among the brilliant stars of winter.

COMET SCHAUMASSE RETURNS

The second half of February is an excellent time to view the return of Comet Schaumasse. Binoculars or a small telescope will show you a 7th- or 8th-magnitude patch of light glowing softly among the background stars of southern Perseus.

Calendar of Events

4 The Moon passes 6° south of Mars, 5 a.m. EST

6 Full Moon is at 6:55 p.m. EST

7 The Moon is at perigee (222,392 miles from Earth), 3:22 p.m. EST

9 Saturn is in conjunction with the Sun

10 The Moon passes 6° south of Jupiter, 5 p.m. EST

13 Last Quarter Moon is at 9:57 a.m. EST

15 Mars is stationary

16 Asteroid Hebe is at opposition

21 Mercury is at greatest eastern elongation (18°)
New Moon is at 8:05 a.m. EST

22 The Moon is at apogee (252,666 miles from Earth), 12:57 p.m. EST

23 The Moon passes 3° north of Mercury, 2 a.m. EST

24 Venus is at greatest brilliancy (–4.6 magnitude)
The Moon passes 0.5° south of Venus, 11 p.m. EST

Eye on the Sky

by Deborah Byrd

MARS BRIGHT IN THE EVENING SKY

After the Sun sets this month, look to the east for a bright, steady point of reddish light ascending in the darkening sky. It's not the brightest object in this region of the sky, but it holds its own in a region of many brilliant stars. This is Mars, the Red Planet. In January Earth passed between Mars and the Sun. Now Mars is well-placed for viewing in the early evening sky. Casual stargazers are more likely to notice the Red Planet this month than last because it appears high in the east shortly after the Sun goes down.

Mars shines at magnitude –0.5 among the stars of Gemini. Though that makes it brighter than every star except Sirius and Canopus, it won't be for much longer. Mars is falling behind Earth in its larger and slower orbit around the Sun and thus will fade over the coming months. Note the brightness of Mars relative to the brilliant winter stars nearby. Then watch as the weeks pass to see the inevitable dimming of the planet's light.

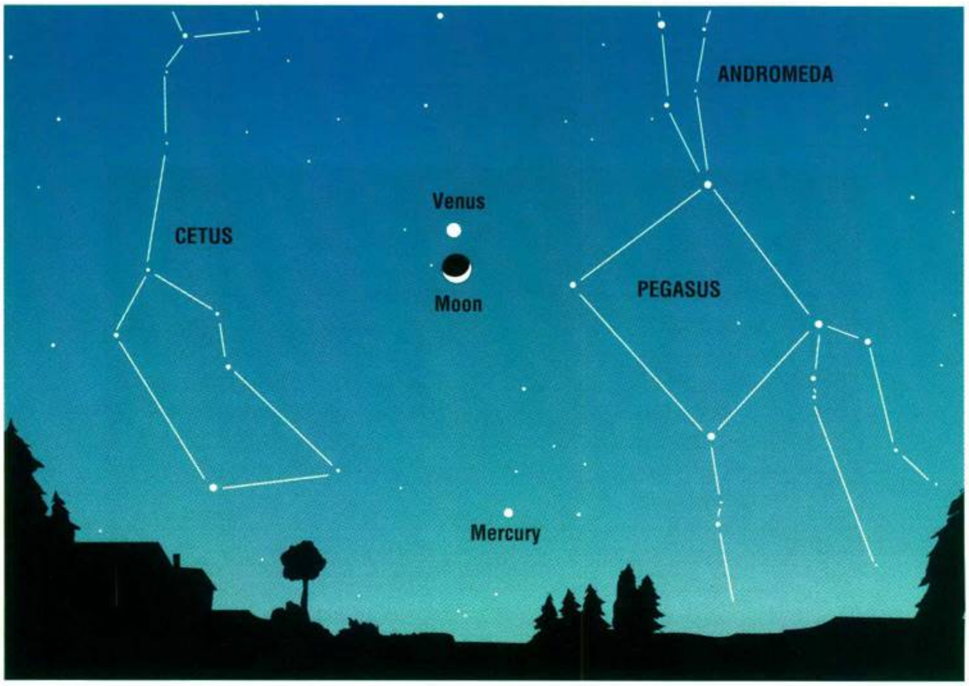
THE SHOWY INNER PLANETS

When you shift your gaze to the western evening sky, you'll immediately see Venus against the twilight glow. Few things in backyard observing are as easy as viewing the brightest planet. Venus always appears as a beacon whose brilliance is unmatched by that of any star or other planet.

Last month Venus reached greatest eastern elongation, its maximum apparent distance from the Sun for this evening apparition. Now the planet is starting to edge closer to the Sun's glare, though it remains quite high and very conspicuous in the twilight sky throughout February. On the 24th, Venus appears brighter than at any other time during this apparition. At magnitude –4.6, the planet is even bright enough to cast a faint shadow. You're most likely to see a shadow if you project it onto a white background, like the snow so common in the north this time of year.

Venus has company in the western twilight sky this month. Mercury climbs out of the horizon haze to join its neighboring planet. Mercury is not nearly as bright as Venus and it never achieves the altitude of its sister planet. Still, if you've followed Venus the past few months, you'll enjoy the sight of another planet shining below it.

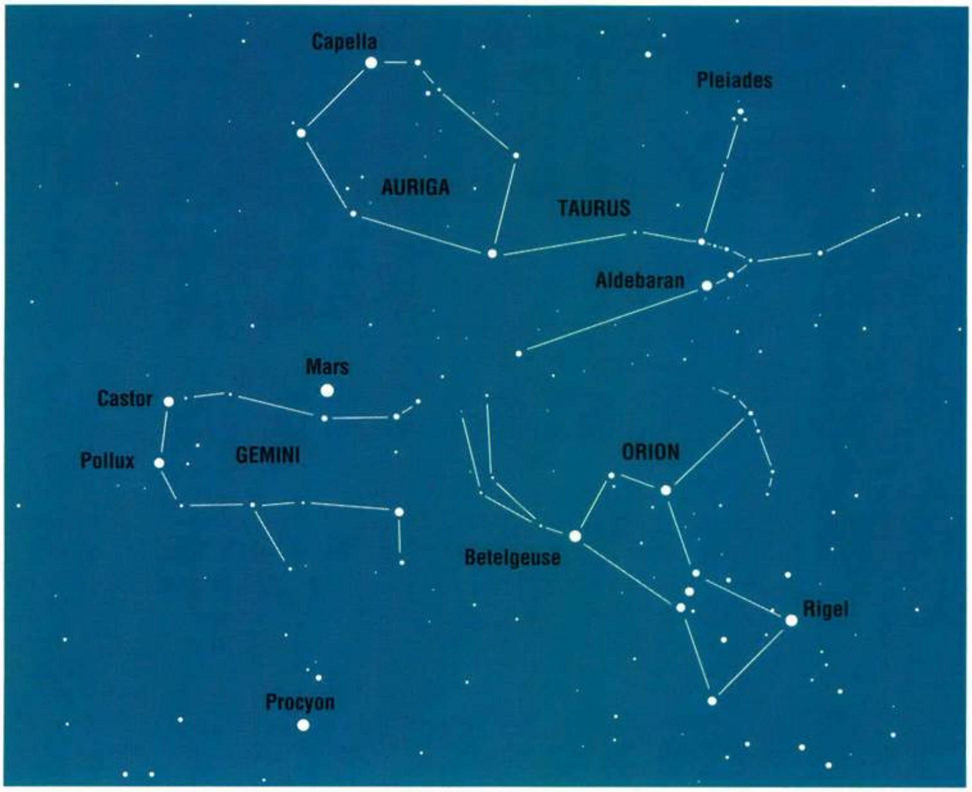
A PRETTY PAIRING of Venus and the Moon graces the western twilight sky on the evening of February 24. Also look for the elusive planet Mercury, which lies about 20° below the bright pair.



Mercury reaches greatest elongation on February 21. It then lies 18° east of the Sun and shines at magnitude –0.4. A slim crescent Moon passes 4° from Mercury on the evening of February 22. Two nights later, you'll see a slightly fatter crescent less than 1° from Venus — a striking sight. (For more on observing Venus and Mercury, see "Winter's Evening Planets" on page 60.)

VIEW THE ZODIACAL LIGHT

In my column, I often use the word "ecliptic" loosely to mean the path of the Sun, Moon, and planets across the sky. More precisely, the ecliptic is the apparent path of the Sun around our sky, which is a reflection of Earth's own orbital motion about the Sun. Because the Moon and most planets orbit in nearly the same plane as Earth, they always appear



THE BRILLIANT STARS of winter form a stunning backdrop for Mars this month. Look for the planet's distinctive ruddy light high in the east during the early evening hours.

within a narrow band called the zodiac, which is centered on the ecliptic. The angle of the ecliptic relative to the horizon changes with the seasons and with your location on Earth. In late winter and early spring, the angle between the ecliptic and the western evening horizon is steeper than at any other time of year. That's why Mercury and Venus are particularly easy to see now — their angular distance from the Sun translates to a distance nearly straight up from the horizon.

But there's another phenomenon you should look for caused by the steep angle of the ecliptic to the horizon. The zodiacal light is a large, faint, eerie pyramid of light visible in the west at the end of evening twilight. You'll need a dark sky to see the zodiacal light. I've seen it many times from deep in the heart of West Texas, while my fellow stargazers in the north and northeast often comment that they've never seen it. Though you'll occasionally see a crescent Moon shining in its midst, too much moonlight washes the zodiacal light from view. You can easily tell this light from ordinary twilight because it appears only after the last vestiges of twilight have disappeared. It is so lovely and wondrous that I highly recommend a springtime excursion to a dark sky just to see it.

By the way, unlike twilight — which happens because we live on a planet surrounded by air — the zodiacal light could be seen from the airless Moon. It results from sunlight's reflecting off tiny dust grains lying in the plane of the solar system.

JANUARY'S PLANETS

Mercury comes out of the sunset glare before mid-month, appearing as a bright object in the western twilight sky. It shines at magnitude –0.4 on February 21, when it reaches greatest elongation. Mercury's companion this month is the much-brighter planet **Venus**, which lies above it in the twilight sky. Venus reaches greatest brilliancy on February 24, when it shines at magnitude –4.6.

During the early evening when Mercury and Venus dominate the western sky, **Mars** is conspicuous in the east. It wheels across the sky during the night and sets a few hours before sunrise.

When you gaze eastward during the evening hours, try to identify Mars by its apparent failure to twinkle. Some people say they can't tell the difference between the relatively steady light of a planet and the twinkling of a star, but there is a difference. See if you can tell by carefully contrasting Mars' light with that of the bright winter stars lying nearby.

Jupiter is easy to pass over in all the excitement over Mercury, Venus, and Mars. Yet this giant planet soon will become the evening sky's main attraction. It rises in midevening this month and shines very brightly — brighter than any star — at magnitude –2.3. It dominates February's night sky from late evening until dawn. Jupiter seems even more prominent because it appears in a star-poor region of the heavens, within the boundaries of the constellation Virgo. The only bright star nearby is 1st-magnitude Spica, which lies about 10° southeast of the giant planet.

Saturn can't be seen this month. It is in conjunction with the Sun on February 9, meaning it lies behind the Sun as seen from Earth. Sharp-eyed observers will spot it rising shortly before dawn in early March.

THE STARRY SKY

There are so many bright stars visible this month — and such a fine collection of planets — that it's easy to overlook one of the winter sky's lovelier sights. If you're gazing at a dark sky, you might even notice it as a hazy patch among the stars. Yet this object is somehow forever elusive. When my eyes chance upon it, I sometimes pause for a moment, wondering just what it might be.

Then I remember. It's the Beehive in the constellation Cancer! It is nothing less than a cluster of hundreds of stars whose light, which covers an area more than twice that of the Full Moon, blurs together over 500 light-years of distance. This is an object for raising your binoculars skyward, a gesture sure to reveal this hazy patch as a mass of glittering stars.

The Beehive is an open star cluster. Its stars were born from a single cloud of interstellar gas and dust, and they're still weakly bound by gravity. Our Sun may have been born in a similar cluster. Ultimately, clusters of this sort dissolve, and the member stars drift away to pursue their own orbits around the center of the Milky Way Galaxy.

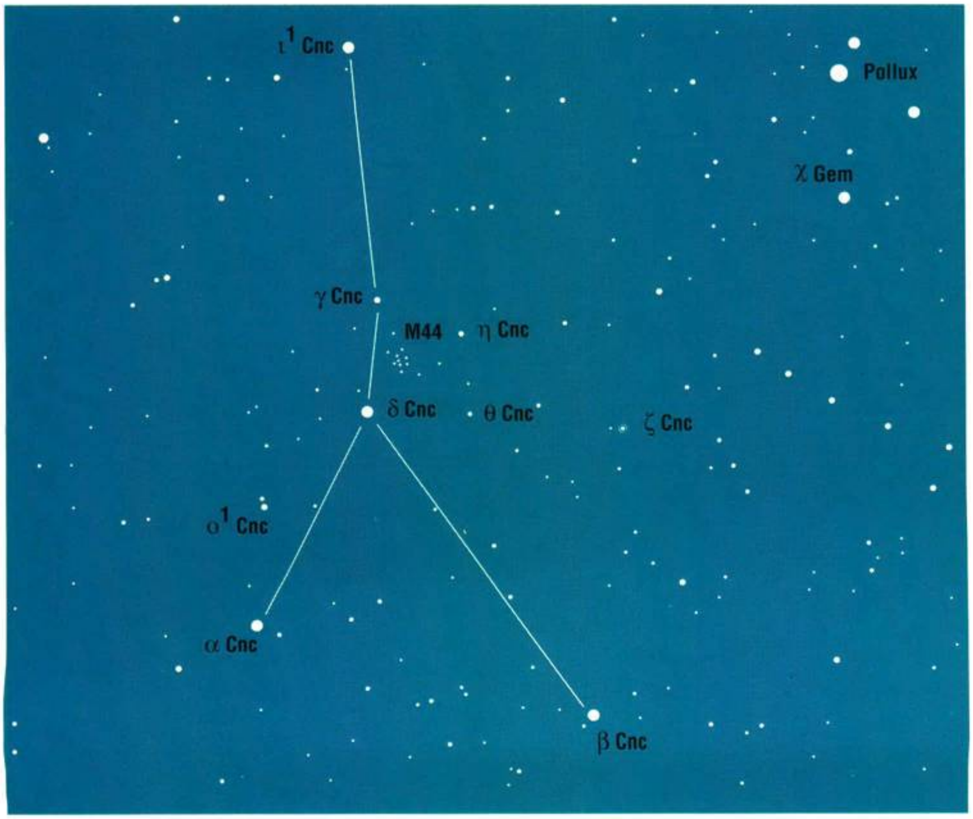
The ancient stargazers knew nothing of star birth or evolution, and to them the Milky Way was only a marvelous river of light spun across the sky. But the Beehive has been recognized for thousands of years. It was frequently used to forecast the weather, since high clouds approaching before a storm easily blot it from view. An older but still-used name for the Beehive is Praesepe, which is Latin for "the manger." Two donkeys, represented by nearby stars, are supposed to be feeding from it.

The name "Beehive" stems from English skylore. Imagine some stargazer with excellent eyesight gazing up and seeing this cluster's stars. Keen eyes or binoculars reveal that the cluster bears a faint resemblance to a swarm of bees.

The Beehive lies nearly at the center of Cancer, one of the constellations of the zodiac. Cancer represents a crab that was supposedly raised into the heavens after being squashed by Hercules during a battle. The Tropic of Cancer — the latitude where the Sun appears directly overhead on the summer solstice — is named for this constellation. That's because several thousand years ago when the ancients coined the name, the Sun resided in Cancer on the first day of summer. ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. It now can be heard on more than 115 radio stations.

CANCER THE CRAB is a fairly inconspicuous constellation lying southeast of Gemini's brightest star, Pollux. You can spot Cancer and its remarkable binocular object, M44 (the Beehive star cluster), high in the east during midevening.



Through the Eyepiece by Rick Shaffer

MERCURY AND VENUS IN VIEW

Mercury makes its best evening appearance of 1993 this month. The innermost planet reaches greatest elongation on February 21, when it lies 18° east of the Sun. Not to be outdone, the brightest planet, Venus, dominates the same part of the western evening sky.

Mercury can appear as far as 28° from the Sun, so this apparition may seem rather ho-hum in comparison. But for Northern Hemisphere observers, the solar system geometry for this apparition is nearly perfect. Just after sunset in February, the ecliptic meets the western horizon at a steep angle, approximately 75° as seen from midnorthern latitudes. Mercury lies a bit north of the ecliptic, so almost all of the 18° separation from the Sun translates into altitude above the horizon. Thirty minutes after sunset on the 21st, Mercury appears 11° above the western horizon. Venus, on the other hand, lies a healthy 22° higher.

The innermost planet's telescopic appearance undergoes rapid changes during February. On the 7th, just after Mercury first appears in the evening sky, its 5.4"-diameter disk displays a 91-percent-lit gibbous phase. At greatest elongation on the 21st, the planet appears 7.2" in diameter with a 49-percent-lit phase. And by the end of the month, Mercury shows a disk measuring 8.8" across and a slim, 20-percent-lit crescent.

Venus adds spice to the western evening sky, though its telescopic appearance changes at a more leisurely pace than Mercury's does. On February 1, Venus appears 28.0" across and shows a 44-percent-lit crescent phase in the eyepiece. By the end of the month, Venus' apparent diameter has swelled to 41.1" and its phase has dwindled to 24 percent lit. I won't devote any more space to these apparitions of the inner planets because Edmund A. Fortier has written an entire article on them. See "Winter's Evening Planets" on page 60.

COORDINATES FOR COMET SCHAUMASSE

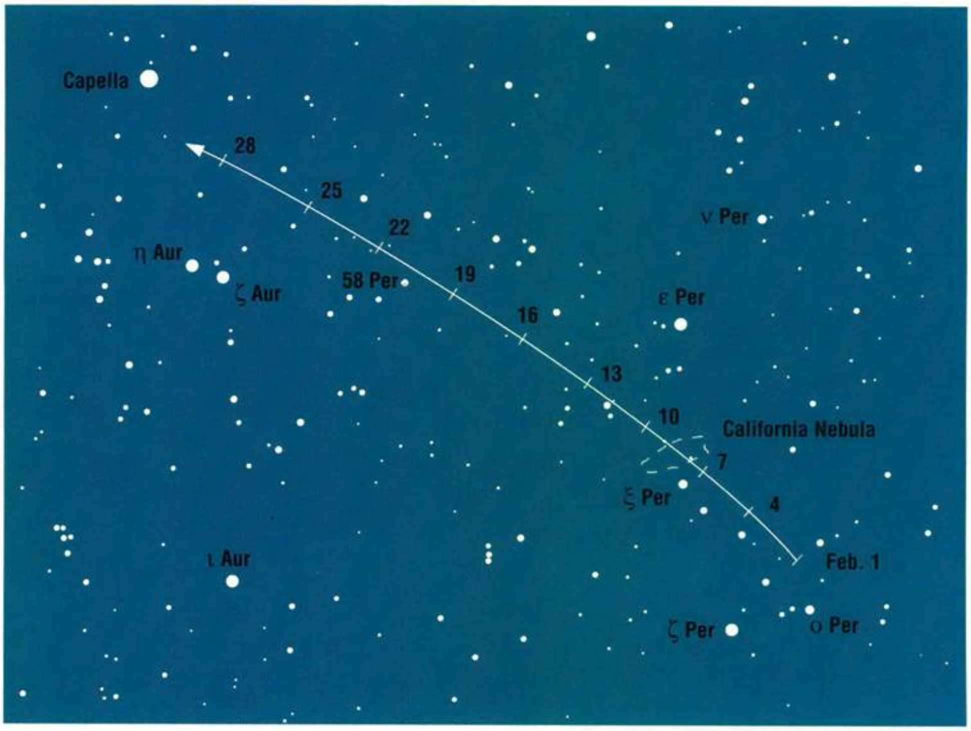
Date	R.A. (2000)	Dec.
Feb. 1	3h45.5m	33°36'
Feb. 4	3h50.7m	34°51'
Feb. 7	3h56.7m	36°06'
Feb. 10	4h03.6m	37°21'
Feb. 13	4h11.4m	38°35'
Feb. 16	4h20.1m	39°48'
Feb. 19	4h29.7m	40°59'
Feb. 22	4h40.4m	42°06'
Feb. 25	4h52.0m	43°10'
Feb. 28	5h04.7m	44°09'

COMET SCHAUMASSE RETURNS IN THE EVENING SKY

With the exception of Comet Swift-Tuttle, which was reasonably bright in November and December, we've had a dearth of good comets lately. That run of bad luck changes this month, however, as Comet Schaumasse puts on a respectable show for our viewing pleasure in the evening sky.

Comet Schaumasse orbits the Sun in a highly elliptical orbit that brings it back to the inner solar system every 8.2 years. But each return is not equally good. Fortunately, this return sees the comet well placed for observing in the evening sky during February and March, when it should shine between 7th and 8th magnitude and be easy to pick up in binoculars. Though perihelion comes on March 4, your best bet for observing Comet Schaumasse comes during the last two weeks of February, when the Moon is out of the sky.

As February begins, the comet lies just 9° north of the Pleiades star cluster. From there it heads northeast, traversing southern



FOLLOWING HARD ON SWIFT-TUTTLE'S HEELS is Comet Schaumasse, which traverses southern Perseus during February. Positions for the 7th- or 8th-magnitude comet are shown for 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST).

Perseus and pushing into western Auriga by month's end. On February 8 and 9, Schaumasse passes in front of the California Nebula, creating a fine target for astrophotographers. During the first week of March, the comet passes 1° south of Capella.

You should first view Comet Schaumasse at low power. I recommend using binoculars or an eyepiece that yields an exit pupil of between 5.5 and 7 millimeters. (The exit pupil equals the focal length of the eyepiece divided by the f/ratio of the telescope or, equivalently, the aperture divided by the magnification.) This will give you a large field and good contrast. If the comet develops much of a tail, it will show up best at this power. If you have trouble seeing the tail, try averted vision by looking toward the edge of the field. This will make use of the more light-sensitive part of your retina.

Next, bump up the power to give an exit pupil of 3 to 4 millimeters. This will yield a good view of the inner tail and the coma of the comet. Give the coma — the "head" of the comet that's composed of gases released from the comet's nucleus — a long look to see if it has any structure or asymmetry.

To view structure such as jets and plumes in the inner coma of Schaumasse, use an eyepiece that yields an exit pupil of 0.5 to 1 millimeter. If the seeing isn't great, this may spread the comet's light too much to give a good view. If that happens, lower the power to avoid the effects of poor seeing.

MARS' LAST 1993 HURRAH

February finds Mars high in the east as evening twilight fades. The Red Planet remains bright throughout the month, fading from magnitude –0.9 on the 1st to –0.1 on the 28th. Mars also presents a large image to Earthbound observers — the planet's disk subtends an angle of 13.1" on February 1, which shrinks to 10.3" across by February 28.

Unfortunately, February is probably the last month during the current apparition to observe Mars in detail. Most experienced planetary observers agree that the subtle surface markings Mars is famous for become difficult to see when the disk falls below 10" across.

To determine which portion of the Martian disk is visible at a given time, use the table of central meridians on the opposite page. (The central meridian is the longitude that cuts through the center of the planet's Earth-facing hemisphere.) Then to identify the features you'll be seeing, refer to the map of Mars shown on page 78 of the November 1992 issue.

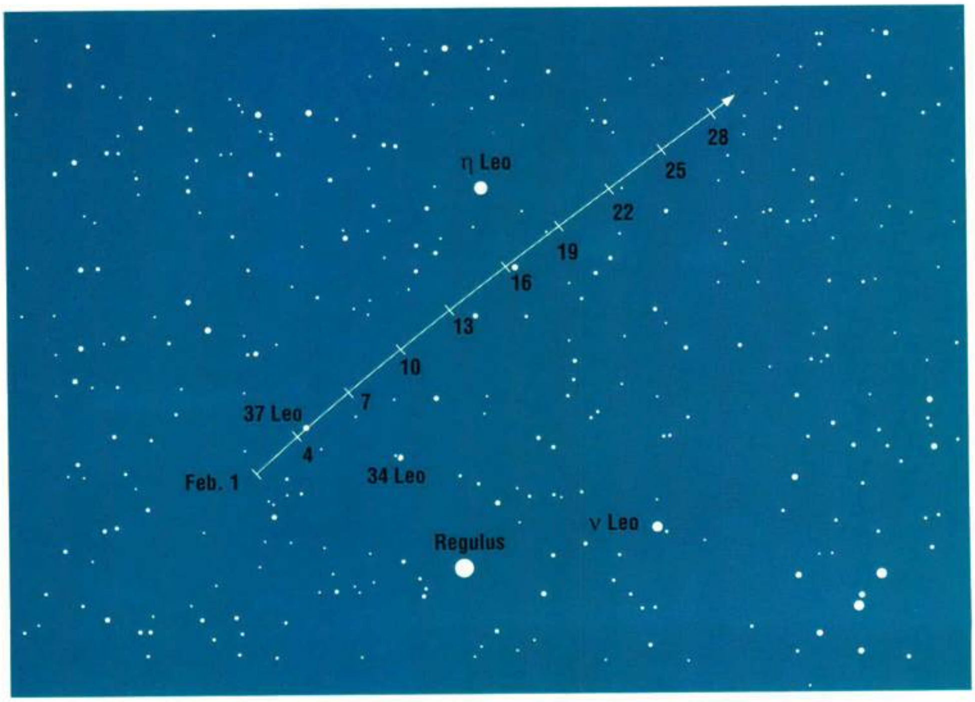
When you view Mars at relatively low power, the feature that first strikes you is the north polar cap. The cap appears as a bright white patch on the northern tip of the otherwise ocher-colored planet. Because it is now springtime in Mars' northern hemisphere, the cap has started to melt, but it should still appear prominent. Astronomers think the cap is composed of both water and carbon dioxide ice.

The other major type of feature you should see are the dark markings known as albedo fea-

COORDINATES FOR HEBE

Date	R.A. (2000)	Dec.
Feb. 1	10h19.3m	13°08'
Feb. 4	10h16.8m	13°40'
Feb. 7	10h14.3m	14°11'
Feb 10	10h11.6m	14°43'
Feb. 13	10h08.9m	15°14'
Feb. 16	10h06.1m	15°45'
Feb. 19	10h03.3m	16°16'
Feb. 22	10h00.6m	16°45'
Feb. 25	9h57.9m	17°13'
Feb. 28	9h55.3m	17°40'

ASTEROID 6 HEBE reaches opposition on February 16, when it shines at 9th magnitude about one-quarter of the way between Eta (η) Leo and Regulus. Positions are shown for 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST).



Don Parker

MARS OFFERS A WEALTH OF DETAIL for observers, and the view changes constantly as Mars rotates. Central meridians shown above (left to right) are 169°, 257°, and 345°.

tures. These are areas of bare rock that have not been covered by the constantly shifting orange-red sands of Mars. Slow changes in the appearance of these features result when the darker surface is either covered or uncovered by sand.

To punch up the contrast of your view of Mars, try using a red or orange filter (Wratten #s 21, 23A, 25, or 29). This lets the light reflected off the orange-red Martian sand through to your eye while blocking the darker, brown-gray color of the areas not covered by sand. The dark areas will appear darker than without the filter, allowing you to see more detail.

With Mars now high in the early evening sky, you should begin observing it as soon as you can after sunset. This strategy lets you view the planet when it is farther above the horizon. The higher Mars is, the less atmosphere between it and your eye, and the less atmosphere, the less turbulence to cause poor seeing.

TELESCOPIC PLANETS

Jupiter lies in the morning sky this month, moving toward opposition in late March. The best time to observe the giant planet is between roughly 2 a.m. and 4 a.m., when the seeing has settled down and the planet is transiting the meridian.

After the strain of viewing Mars' small disk, observing Jupiter's 41.5"-diameter disk — about four times larger than Mars' — should be a pleasure. Look for the alternating light zones and dark bands running parallel to the planet's equator and the Great Red Spot nestled into the South Equatorial Belt. The four small points of light to either side of Jupiter are the planet's Galilean satellites, which change position noticeably from one night to the next.

The outer gas giant planets offer far less than Jupiter. **Saturn** is lost in the Sun's glare throughout February, coming into conjunction with the Sun on the 9th. **Uranus** and **Neptune** are slightly better-placed, though not much. They were both in conjunction with the Sun (and each other) in January, and in February they can be seen low in the southeast during morning twilight. Uranus appears 3.4" across and shines at magnitude 5.8, while Neptune is 2.2" in apparent diameter and shines at magnitude 8.0.

ASTEROIDS IN THE EYEPIECE

The asteroid of the month is **6 Hebe**, which reaches opposition on February 16. This chunk of rock, 200 kilometers in diameter, is a 9th-magnitude object located just a few degrees north of Regulus in Leo. You can find it with the help of the map or table of coordinates on the opposite page. □

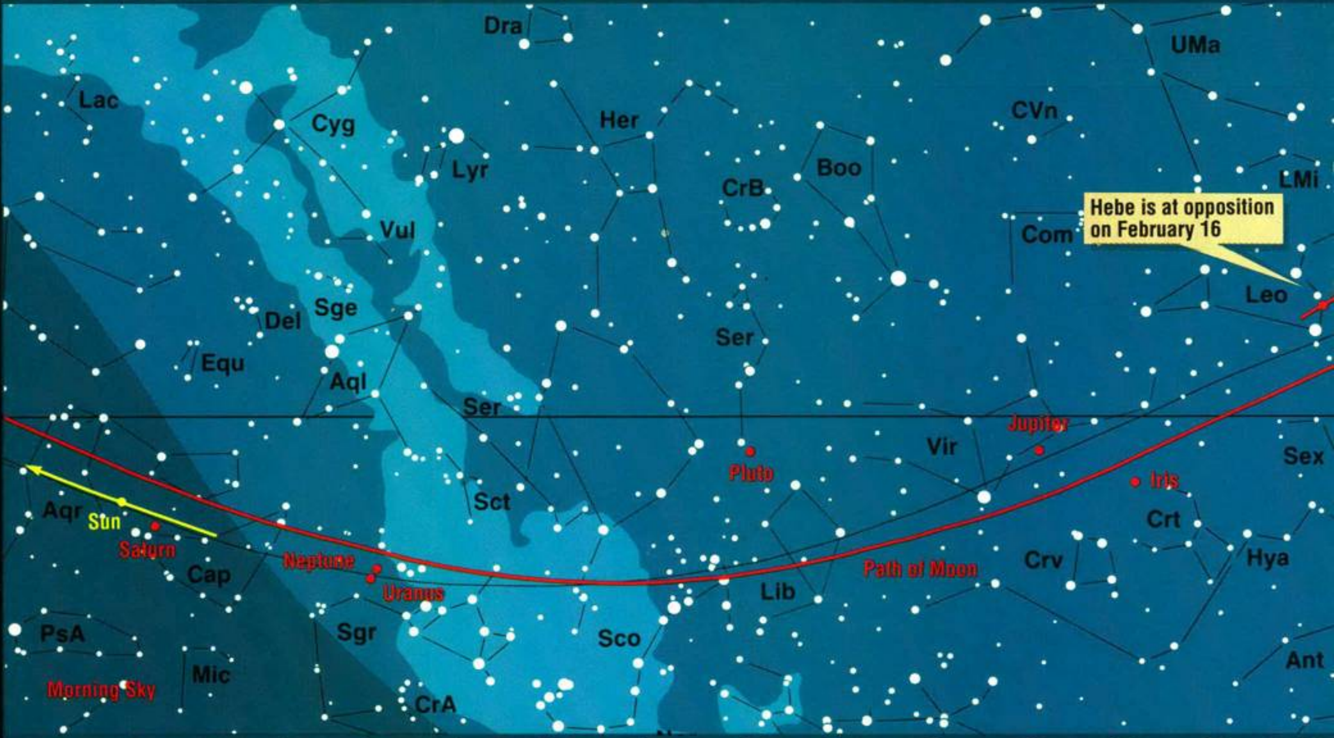
Rick Shaffer is an engineer and writer in the aerospace industry in Southern California.

MARTIAN CENTRAL MERIDIANS

Date	Central Meridian
February 1	129°
February 2	120°
February 3	111°
February 4	102°
February 5	93°
February 6	84°
February 7	75°
February 8	66°
February 9	57°
February 10	48°
February 11	39°
February 12	30°
February 13	21°
February 14	12°
February 15	2°
February 16	353°
February 17	344°
February 18	335°
February 19	326°
February 20	317°
February 21	308°
February 22	298°
February 23	289°
February 24	280°
February 25	271°
February 26	262°
February 27	252°
February 28	243°

Central meridians are for 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST). The meridian advances 14.6° each hour.

The Solar System February 1993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Ser
Jupiter
Vir
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Aqr
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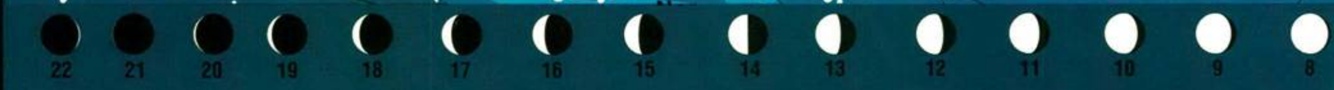
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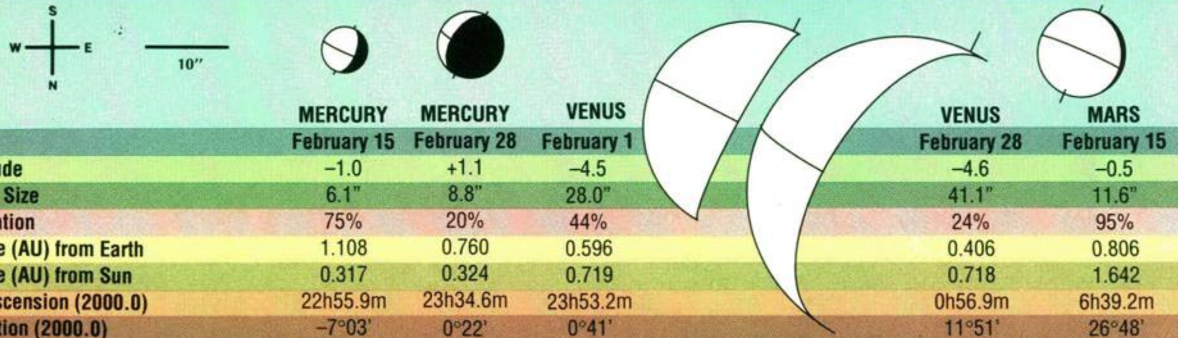
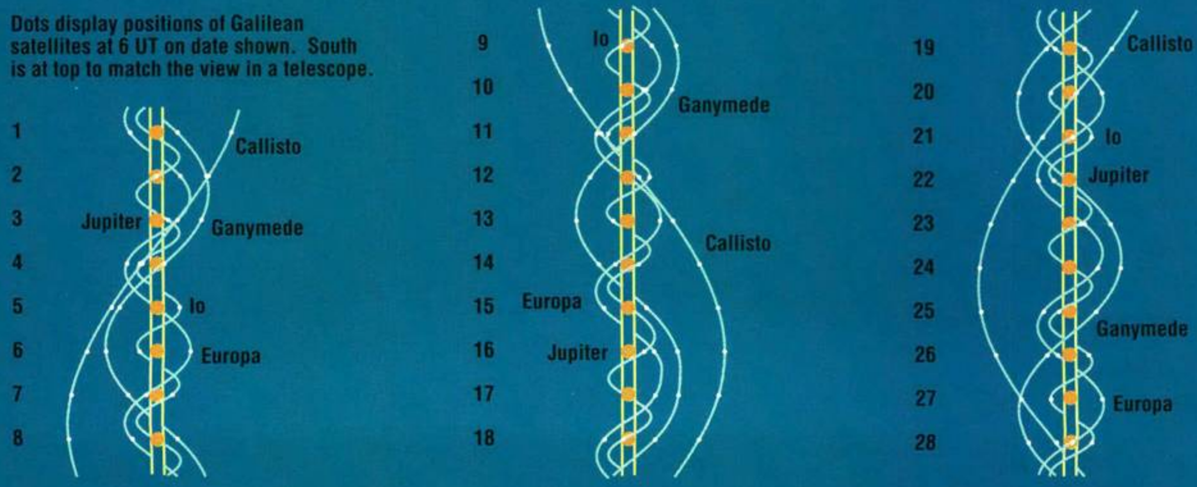
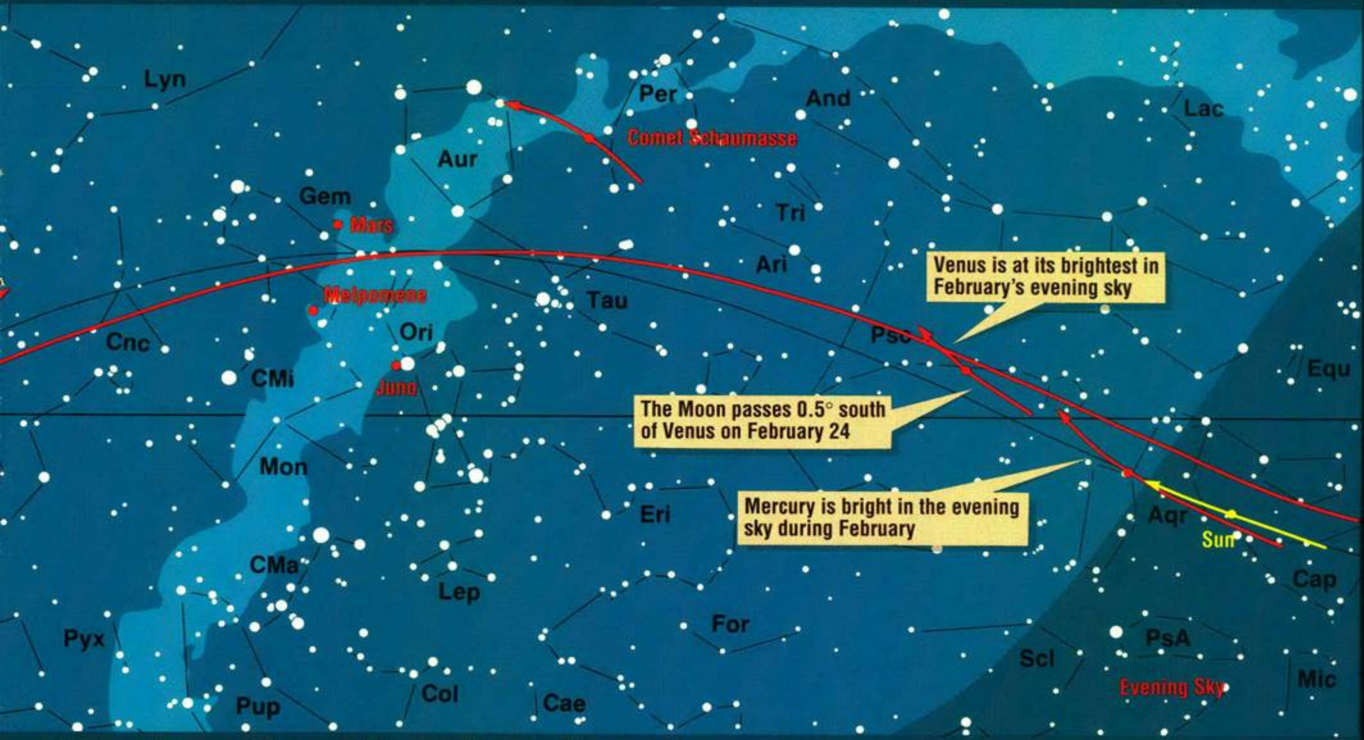


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	February 15	February 28	February 1	February 28	February 15
Magnitude	–1.0	+1.1	–4.5	–4.6	–0.5
Angular Size	6.1″	8.8″	28.0″	41.1″	11.6″
Illumination	75%	20%	44%	24%	95%
Distance (AU) from Earth	1.108	0.760	0.596	0.406	0.806
Distance (AU) from Sun	0.317	0.324	0.719	0.718	1.642
Right Ascension (2000.0)	22h55.9m	23h34.6m	23h53.2m	0h56.9m	6h39.2m
Declination (2000.0)	–7°03′	0°22′	0°41′	11°51′	26°48′

Jupiter's Moons

Dots display positions of Galilean satellites at 6 UT on date shown. South is at top to match the view in a telescope.

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Eri
Aqr
Sun
CMa
Lep
Cap
For
Pyx
Scl
PsA
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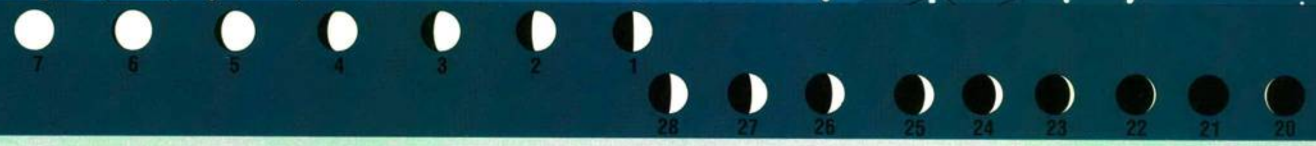
Pup
Evening Sky
Mic

Venus is at its brightest in February's evening sky

The Moon passes 0.5° south of Venus on February 24

Mercury is bright in the evening sky during February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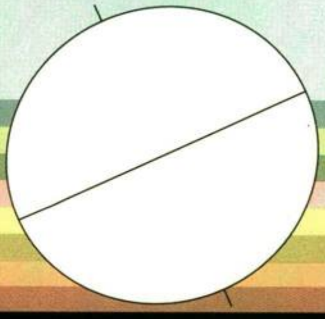
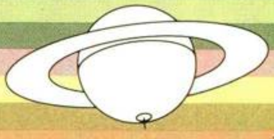
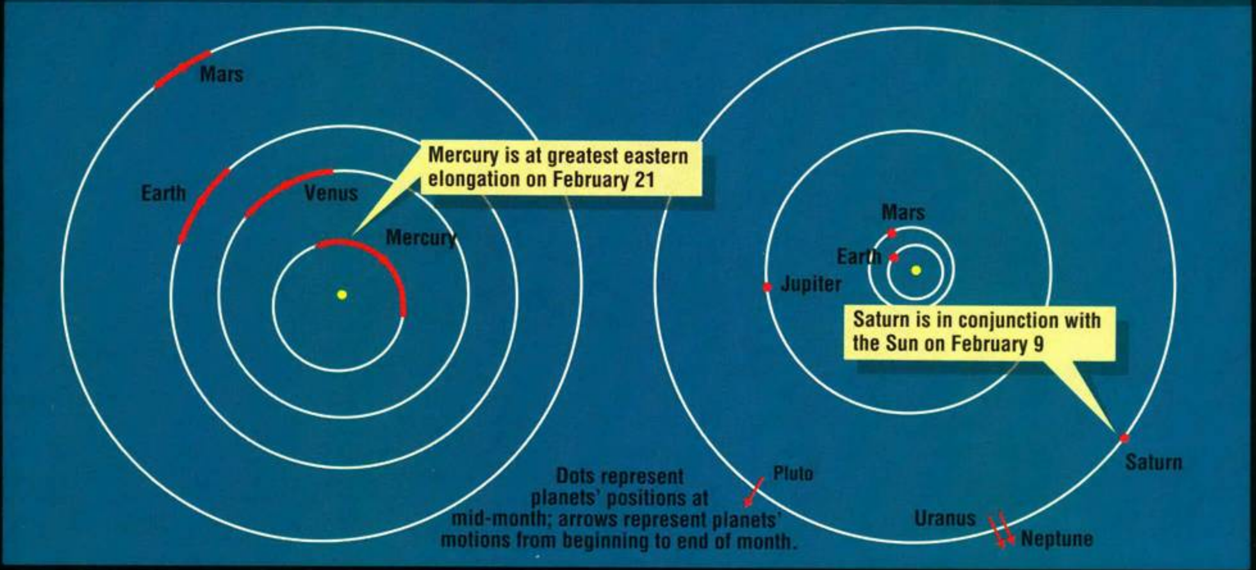




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 28	February 15	February 15	February 15
–2.3	+0.8	+5.8	+8.0	+13.7
41.5"	15.3"	3.4"	2.2"	0.1"
100%	100%	100%	100%	100%
4.739	10.798	20.370	30.977	29.694
5.451	9.852	19.580	30.187	29.724
12h55.1m	21h43.7m	19h28.2m	19h26.5m	15h46.6m
–4°16'	–14°47'	–22°19'	–21°17'	–5°05'

The Planets in Their Orbits


Mars
Earth
Venus
Mercury
Mars
Earth
Jupiter
Pluto
Saturn
Uranus
Neptune

Mercury is at greatest eastern elongation on February 21

Saturn is in conjunction with the Sun on February 9

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

Winter's Evening Planets

Venus and Mercury put on a dazzling show in this winter's evening sky.

by Edmund A. Fortier

Daniel Reilly

VENUS SHINES BRILLIANTLY in the western evening sky in early 1993, much as it did during the 1992 morning apparition shown here.

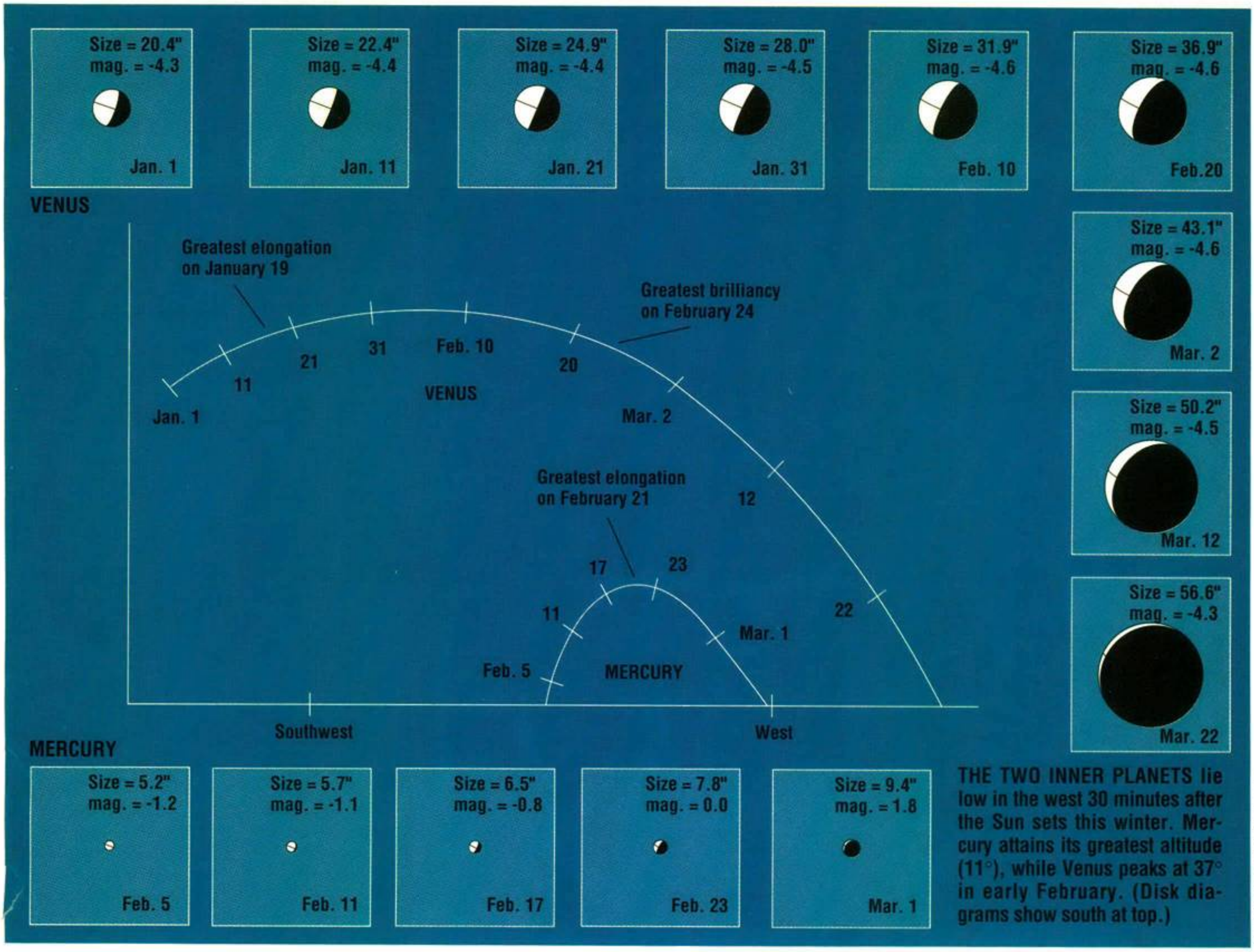
Walk outside on any crisp winter's evening and the brilliant stars of the season immediately draw your eye. Dominating the southeast as twilight fades is the familiar figure of Orion the Hunter with its two luminaries, Rigel and Betelgeuse. A host of other bright stars surround Orion — Aldebaran, Capella, Castor, Pollux, Procyon, and the brightest of all, Sirius.

But if you walk outside some evening this winter, a far more spectacular sight awaits you. The brightest "star" of all — actually the planet Venus — commands the evening sky from January to late March. From its position in the west, Venus overwhelms the other stars, shining over ten times more brightly than Sirius.

Though not nearly as brilliant as Venus, a second, more elusive planet lurks low in the western sky. This is Mercury, the innermost planet and the most difficult of the bright naked-eye planets to see. But if you know when and where to look, Mercury isn't hard to spot. And the good news is that the planet puts in its best evening appearance of 1993 during February.

The Brightest of All

No celestial object is quite like Venus. The most brilliant object in



THE TWO INNER PLANETS lie low in the west 30 minutes after the Sun sets this winter. Mercury attains its greatest altitude (11°), while Venus peaks at 37° in early February. (Disk diagrams show south at top.)

ASTRONOMY: Phil Kirchmeier

the sky after the Sun and Moon, Venus in the early evening sky is a glorious sight. And despite a reputation for being bland and featureless, it is also a splendid object in any telescope, exhibiting a large disk with a constantly changing phase.

This is an ideal time to take up Venus watching. Many backyard observers missed Venus' last apparition because it occurred in the morning sky. This time, however, our sister planet is conveniently placed in the evening sky for the first time since the summer of 1991.

As January opens, look for a pearl-white beacon in the southwest just after sundown. Venus' elevation increases slowly during the next several weeks as the planet approaches greatest elongation — its greatest angular distance from the Sun — on January 19. On that date it shines at magnitude −4.4 and, from mid-northern latitudes, appears some 35° above the horizon shortly after sunset.

Whether you intend to view Venus with the naked eye, binoculars, or a telescope, the first step is to find an observing site with a clear horizon. Because Venus never strays farther than 47° from the Sun, it always appears low in the sky during twilight. Its height at any elongation depends mostly on the angle of the horizon to the ecliptic — the apparent path of the Sun, Moon, and planets across the sky. But whatever Venus' elevation at dusk, the longer you delay observing, the lower it will appear.

Venus' current apparition actually began last June, when the planet was in superior conjunction, or behind the Sun as seen from Earth. Since then Venus has been slowly moving away from the solar glare. In August it could be glimpsed just above the horizon at sundown. By December it had grown considerably brighter and was visible for three hours after sunset. The planet reaches greatest elongation on January 19, when it sets nearly four hours after the Sun.

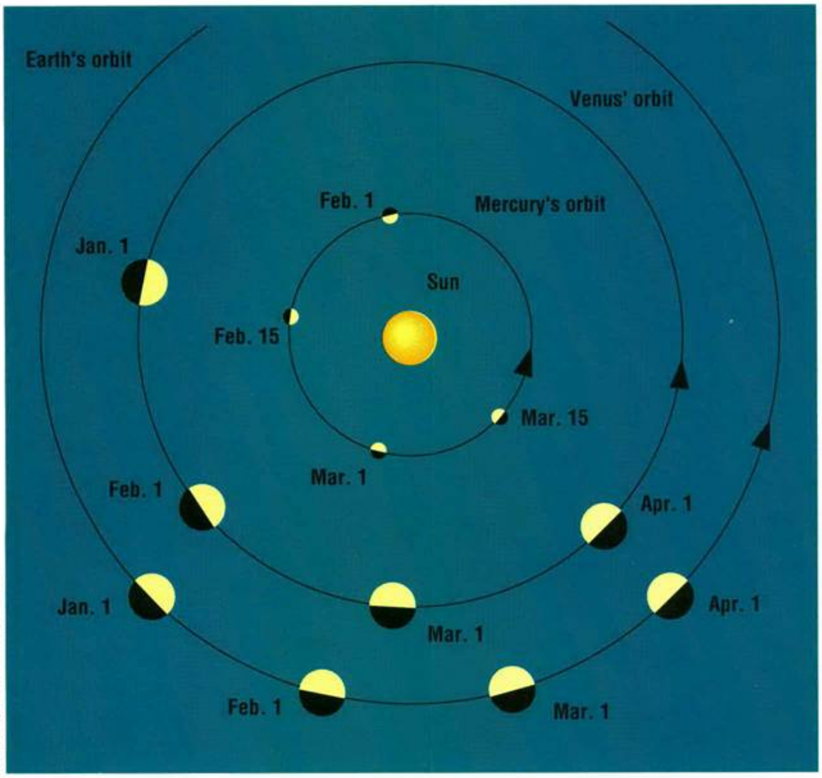
After greatest elongation, Venus continues to swing toward Earth. Surprisingly, however, Venus appears even higher in the sky in early February than it does at greatest elongation. That's because the angle formed by the ecliptic and the horizon grows progressively steeper in February, more than offsetting Venus' decreasing separation from the Sun.

Moreover, Venus appears slightly brighter in February because it is closer to Earth. It reaches greatest brilliancy on the 24th, when it shines at magnitude −4.6. But as the planet's angular distance from the Sun continues to decrease in late February and March, it slips deeper into the twilight. If you have a clear horizon, see how long you can keep Venus in view before it finally disappears in late March. The planet passes between Earth and the Sun, a configuration called inferior conjunction, on April 1.

A Close-up View

Although Venus is a dazzling sight to the naked eye, without optical aid you can follow only the planet's changing brightness and position. A telescope lets you view two fascinating facets of Venus — its changing size and phase.

If you have never observed Venus with a telescope, now is the time. Because the planet is so bright, even a 2.4- or 3-inch refractor provides excellent views. And a telescope in the 6- to 8-inch range reveals just about everything the planet has to offer backyard observers. But no matter what your telescope, keep in mind that Venus doesn't bear magnification well because it never strays far from the horizon. Use the highest power you can that still delivers a crisp, sharp image.



ASTRONOMY: Phil Kirchmeier

MERCURY AND VENUS appear bigger in a telescope as their orbital motions bring them closer to Earth, but at the same time we see a smaller fraction of their lit hemispheres.

The best time to observe Venus is within half an hour of sunset. Not only is the planet then higher in the sky, but also the bright twilight sky softens its glare and makes it easier to spot elusive markings in the cloud layer that hides the surface from view. On these chilly winter afternoons, it's a good idea to set up your telescope about an hour before sunset. That allows ample time for it to match the outside air temperature. Atmospheric seeing generally improves late in the day — an advantage you don't want to lose by viewing Venus through turbulence created by a warm scope.

When you first view Venus, you'll probably notice that its disk is not quite round. Because planets that orbit the Sun inside Earth's orbit pass both in front of and behind the Sun, they exhibit phases just as the Moon does. Venus was "full" at superior conjunction last June, when its Earth-facing hemisphere was fully illuminated. By the time it had moved far enough from the Sun in the sky to be easily visible in backyard telescopes, the planet appeared in a gibbous phase. In January, Venus shrinks even more, reaching half-phase near the date of greatest elongation.

After greatest elongation, Venus' appearance changes much more rapidly. By February 1, Venus appears 28.3" in apparent diameter and its phase has shrunk to a 44-percent-lit crescent. At greatest brilliancy on the 24th, the planet appears 39.2" across and its disk is only 27 percent illuminated. And on March 15, the brilliant planet measures 52.3" in apparent diameter while its phase has slimmed to a minuscule 10 percent lit.

Mercury, a Miniature Venus

Mercury lacks the brilliance and easy visibility of its neighbor Venus. In fact, many backyard observers have never even seen the planet. But it is not difficult to see if you have a clear, unobstructed horizon and know where to look for it.

The best time to see Mercury in the evening sky in 1993 is during February. The innermost planet has its finest evening apparition of the year at a time when Venus can help point the way to it. If you want to spot Mercury with your naked eye, look for it around the time of its greatest elongation on February 21. For observers at mid-northern latitudes, it then shines at magnitude –0.4 and lies 11° above the western horizon 30 minutes after the Sun sets. That places it almost directly below Venus, which then lies 34° high. If you don't spot it at first with your naked eye, use binoculars to locate it. If you then put the binoculars aside, you should be able to see it without optical aid.

The same aspects that cause Venus to be visually exciting in a backyard telescope also make Mercury a worthwhile target. The major differences are that Mercury appears much smaller in the eyepiece and goes through its changes much faster.

When Mercury first becomes visible in the evening sky around February 5, it appears 5.2" across and 94 percent lit. Just two weeks later, at greatest elongation, Mercury's disk has grown to 7.2" in apparent diameter and its phase is down to 49 percent illumination. Mercury sinks toward the horizon rapidly in early March. On the 2nd, it displays a disk 9.6" across while its phase is a slender, 10-percent-lit crescent.

Keeping a close eye on Venus and Mercury this winter will provide you with hours of viewing pleasure. But the pleasure won't continue this spring. Venus emerges from inferior conjunction around mid-April, when it is west of the Sun and visible only in the morning sky. For that reason, it likely won't remain high on your "must see" list. Not until the summer of 1994 will our sister planet again grace the evening sky.

Mercury likewise heads to the morning sky after inferior conjunction, where it has a poor apparition in April. It returns to the evening sky in June, though it appears lower than in February and Venus won't be there to act as a guide for locating the elusive planet. So don your winter coat and head outside — you don't want to miss the two inner planets' grand show. ☐

Edmund A. Fortier is an avid amateur astronomer living in North Scituate, Massachusetts. His last article was "Exploring our Galactic Neighbors" in the October 1992 issue.

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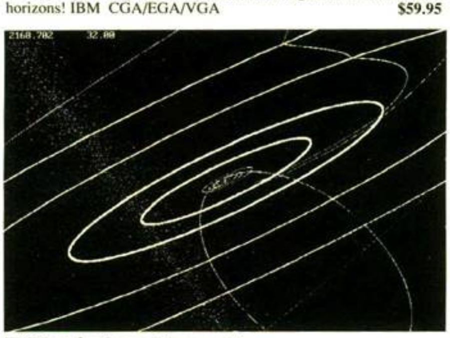

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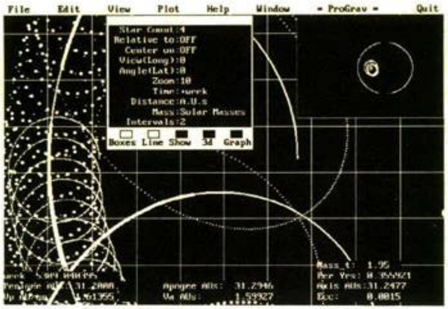

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Va AUs: 1.59927
Mass_t: 1.95
Per Yrs: 0.355921
Axis AUs:31.2477
Ecc: 0.0815

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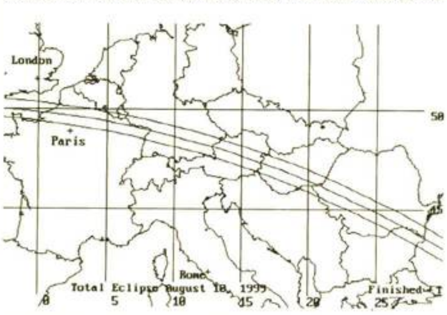

☐ **SunTracker Plus**™ All features of the regular SunTracker and: Hi-res, 16 color EGA/VGA modes. Width of totality path is visible on screen by plotting the bounds of totality = 100%. Eclipse paths plot in black for total eclipses; annular paths in white. Bounding lines are red, oceans blue and land areas are green. Accepts as input the Saros number, a numbering convention for 18 year intervals between similar eclipses. Use Saros numbers to watch a series of eclipses. A Saros series table for 5729 BC to 6627 AD is included. Screen includes path summary table, date of the eclipse and Saros numbers. Above illustration is Super version. Plus uses full world maps(various orientations)IBM EGA,VGA. **$49.95**

SUPER version Plots eclipse paths on variable scale maps in color. You give center of map & overall size in long./lat. Add titles, cities,etc. Plus version included in Super version. IBM EGA/VGA. **$89.95**

Regular version does calculations and basic B&W world map plots and data of central line, duration, etc. IBM CGA, Apple II, C64 **$29.95**

☐ **Astronomy Lab**™ Learn astronomy with your computer. As 70 page manual text explains a topic simulate it on screen. Functions include: 6 sky views, 12 graphical charts, 12 event reports. Explains solar and lunar eclipses, transits of Venus and Mercury, occultations of stars, Jupiter & its moons, seasons & equinoxes, calendar,more. IBM, harddisk or 3.5" floppy, EGA/VGA **$59.95**

☐ **GalaxCrash**™ Simulate the collisions of galaxies on screen. Computer calculates the gravitational forces on the stars so that they move in accordance with Newton's laws of motion to show the typical results of colliding galaxies: whirlpools, rings, bridges and other structures. You specify the number of stars in the first galaxy & the mass, location and the velocity of the second, galaxy. IBM CGA graphics **$29.95**

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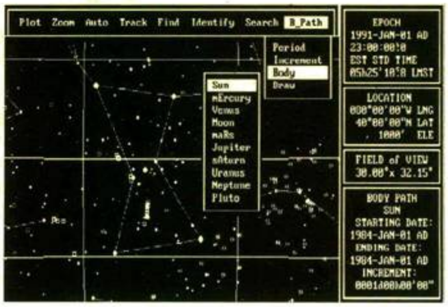

EPOCH
1991-JAN-01 AD
23:00:00:0
EST STD TIME
05h25'10"8 LMST

LOCATION
000°00'00"W LNG
40°00'00"N LAT
1000' ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
0001d00h00'00"

Partial Solar Eclipse
Magnitude: 0.170 Obscuration: 0.3%
LAST CONTACT

NGC 3034 Located at TARGET
(CIRCUMPOLAR)
(CIRCUMPOLAR)

☐ **LodeStar Plus**™ All features of 2.1 version and these additions: High resolution 16 colors with EGA/VGA modes. Includes all 7840 NGC galaxies, clusters, nebulae, etc. Options to plot RA&Dec grids and constellation boundaries. Automatically search for and see solar and lunar eclipses, planetary conjunctions, occultations. Plot the paths of Sun, Moon & planets on sky view. Video mode lets you record screens to display later for reference or demonstrations. Calculates parallax, nutation and aberration and ephemeris time corrections for high accuracy. Supports any of 300 printers, dot, laser or jet. Sophisticated interface including pull-down menus and mouse support to easily access all 78 functions. IBM & compat. Hercules, CGA/EGA/VGA. Works with or w/o co-processor. **$149.95**

☐ **LodeStar Plus II** Added features include: Add your own objects in a user database. Assign names to user objects and create detailed images of objects(examples included). Find bright stars, constellations and user objects by name. Optional SAO star database includes 259,075 stars (all stars down to mag. 11.9) for more detailed sky views and charts (needs 8.5 meg hard disk space). Uses more custom assembly language routines for faster operation. **$199.95**
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- ✦ Automatic tracking and plotting at solar, lunar or sidereal rate
- ✦ Simulates daytime, twilight or night sky for date, time, location
- ✦ Image can be normal or reversed as in telescope eyepiece
- ✦ Star Data: HD#, Flamsteed #, Constel., magnitude, color
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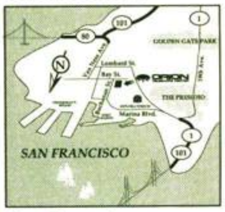

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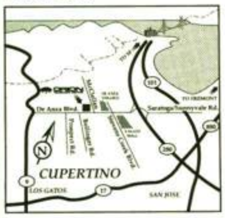

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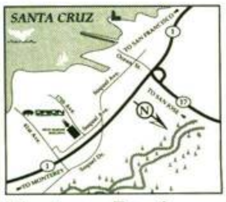

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Fine quality Multi-Coated eyepieces.

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12mm Kellner eyepiece with cable plugs into power panel drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.
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$11.95 ea. (2.43)

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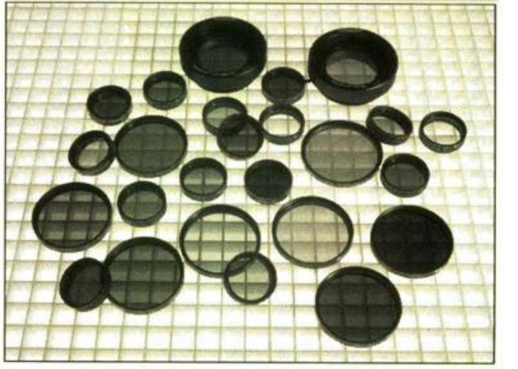

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For Schmidt-Cass.: #8772 ***$99.95*** (3.45)

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These top-quality focusers are designed for Newtonian reflectors. Fit any size tubes.

1.25" Focuser #13007 ***$49.95*** (2.98)

2" & 1.25" Focuser #13003 ***$84.95*** (3.95)

Orion® UltraGuider™

Advanced features at a low price. Use with Meade or Celestron SC. Easily adjustable prism. Ultra-precise helical focus of your eyepiece, adjustable camera focal plane position. #5139 ***$109*** (4.19)

Orion® Premium Off-Axis Guider

High performance, Multi-Coated, precision anodized. Low Orion price! #5144 ***$44.95*** (3.45)

Basic Camera Adapters

Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately). *.965"* #5268 ***$29.95*** (2.98)

1.25" #5264 ***$34.95*** (2.98)

Vari-Power Camera Adapter

Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes. #5262 ***$44.95*** (2.98)

Orion® T-Adapter for SC

For prime focus photography. Use with T-ring to match your 35mm camera. For Meade, Celestron 4", 8", 10", 11", 14" SC. Can be used as 2" camera adapter. #5116 ***$27.95*** (2.98)

Orion® Tele-Extenders

For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender #5125 ***$27.95*** (2.98)

Variable Tele-Extender #5127 ***$37.95*** (2.98)

Orion® Slow Motion Adapter

Attaches to your photo tripod pan head. 2 slow motion control knobs to make precision adjustments in altitude and altazimuth.
#7012 ***$49.95*** (2.98)

FlexiShield™ Dew Caps

Eliminate dew problems with FlexiShield! Better performance, more rugged, and easier storage than rigid dew caps. Forms into a tube with the velcro closure, opens flat for easy storage and transportation. Fits your telescope tube snugly, with wide rubber padding and full length velcro closure—needs no screws. Models to fit most telescopes.
8" Celestron/Meade Schmidt-Cassegrains

#4200 ***$39.95*** (2.98)
Plus nine other models for scopes 3.5" to 14"—Call toll-free!

Orion® Dew Zapper

Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.
8" Dew Zappers —fit all Meade & Celestron 8" Schmidt-Cassegrains
DC Model #3503
AC Model #3504 ***$44.95*** (2.98)

10" Dew Zappers—fit all Meade 10" Schmidt-Cassegrains
DC Model #3506
AC Model #3508 ***$49.95*** (2.98)

Dew Remover Gun

Moisture that interferes with viewing dissipates quickly with this 12V DC, 156 watt warm air gun. Has 4-1/2' cord. #5601 ***$19.95*** (2.78)

Metal-Reinforced Accessory Cases

Keep accessories and camera safe and clean. Diced-foam insert can be tailored to your needs. New black & chrome exterior with sturdy handle, two latches, key lock.
Regular Case: 16"x12"x6.5"

#5920 ***$59.95*** (7.10)

Large Case: 19.5"x12"x6.5"

#5921 ***$69.95*** (7.10)

Scope Saver Telescope Covers

Keep your Schmidt-Cassegrain covered and keep the dust and dew away! Fits the telescope either on the tripod or in the case. Blue waterproof nylon fabric. Drawstring closure with cord lock.
8" Model #15130 ***$33.95*** (2.43)
10"-11" Model Fits Meade 10" and Celestron 11"

#15131 ***$39.95*** (2.43)
Ask about other sizes.

Deluxe Eyepiece Case

This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug fit. O.D. 8-1/2"x12-1/2"x3-1/8".

#5913 ***$17.95*** (2.78)

Field Tripod Tote Bag

With padded insert to separate wedge from field tripod during transportation. For wedge combinations of Schmidt-Cassegrains up to 10" aperture. Allows storage without changing polar alignment. Tear and mildew resistant blue Cordura nylon.

#15096 ***$79.95*** (5.19)

Observer's Chairs

Make observing more comfortable and enjoyable with one of these great chairs.
Standard Model—Has adjustable height center column and padded vinyl seat. Folds for easy storage. #5935 ***$39.95*** (4.70)

Deluxe Model—is much heavier-duty, built for professional musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.

#5934 ***$89.95*** (8.02)

12 Amp Hour Porta Pac Battery

Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper. Battery is encased in high impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs. With charger.
#2354 ***$109 ea.*** (8.97)

DUPLICATING YOUR SUCCESS

To give your planetary images the zing you've been looking for, try this pair of photo-duplicating techniques.

Text and photographs by
KLAUS R. BRASCH

THE GREAT RED SPOT on Jupiter pops into view when the original slide (above) is duplicated to enhance color and contrast (opposite page). All photos in this article were made with a 14-inch SCT at f/150.

WHOOPEE! They're in! You pick up a batch of your latest astrophotos from the processor. Your blood is racing like overheated oil in a V8 engine. You can't wait to look at them — you're sure everything you hoped to capture is *there* on film — the subtle dark markings on Mars, the Great Red Spot on Jupiter, and the dazzling rings of Saturn.

Then you look more critically at the slides. You take them home, project them, and scrutinize the screen. Exhilaration wanes and a sinking feeling sets in.

Something is missing. It's not the technical quality of the photos. The focus was sharp, the exposures just fine. Yet the planets you see in your slides lack the snap they had when you viewed them in the eyepiece. The details you have captured appear subtle and show disappointingly low contrast. Despite all your work, they just fall flat.

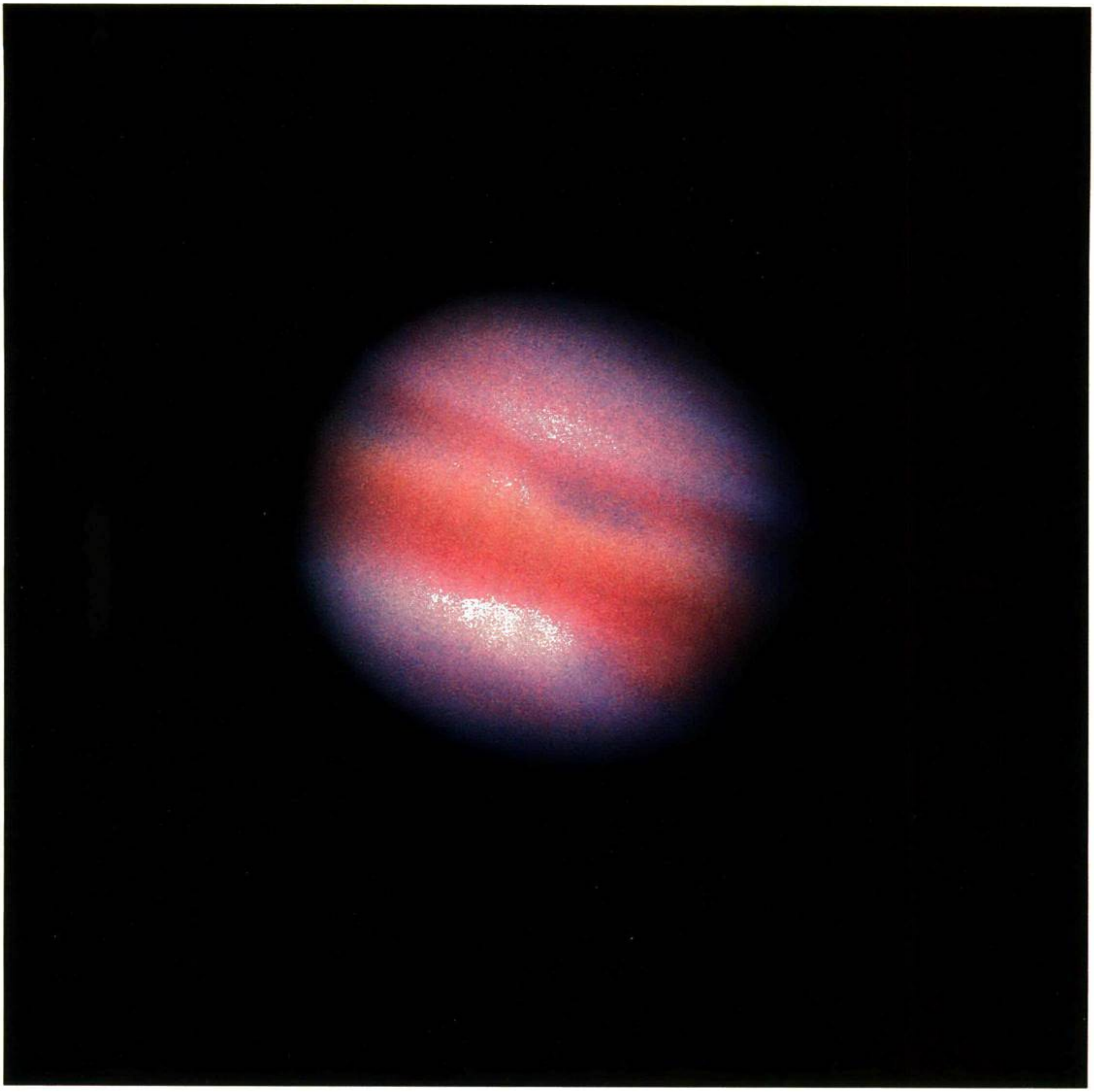
Before you toss your photo gear into the garbage, however, I want to suggest a solution. A number of easy tricks of the trade allow you to enhance your planetary photos.

The most straightforward technique is to duplicate your slides. The methods are simple and the equipment required is basic. You'll need a supply of film and a slide duplicator, a device that attaches to your camera and allows you to rephotograph a slide onto a new piece of film. Duping your slides can produce colorful, contrasty, beautiful shots from your originals.

You can also use another approach, enhancing sketches of planets you make at the eyepiece. Sketches offer the advantage of capturing fine detail that might be lost to film grain. However, you may find accurately positioning details in a planetary sketch difficult. I'll show you a do-it-yourself method that gets sketches and photos working together to produce what I call photo-enhanced sketches.

The Photorealistic Approach

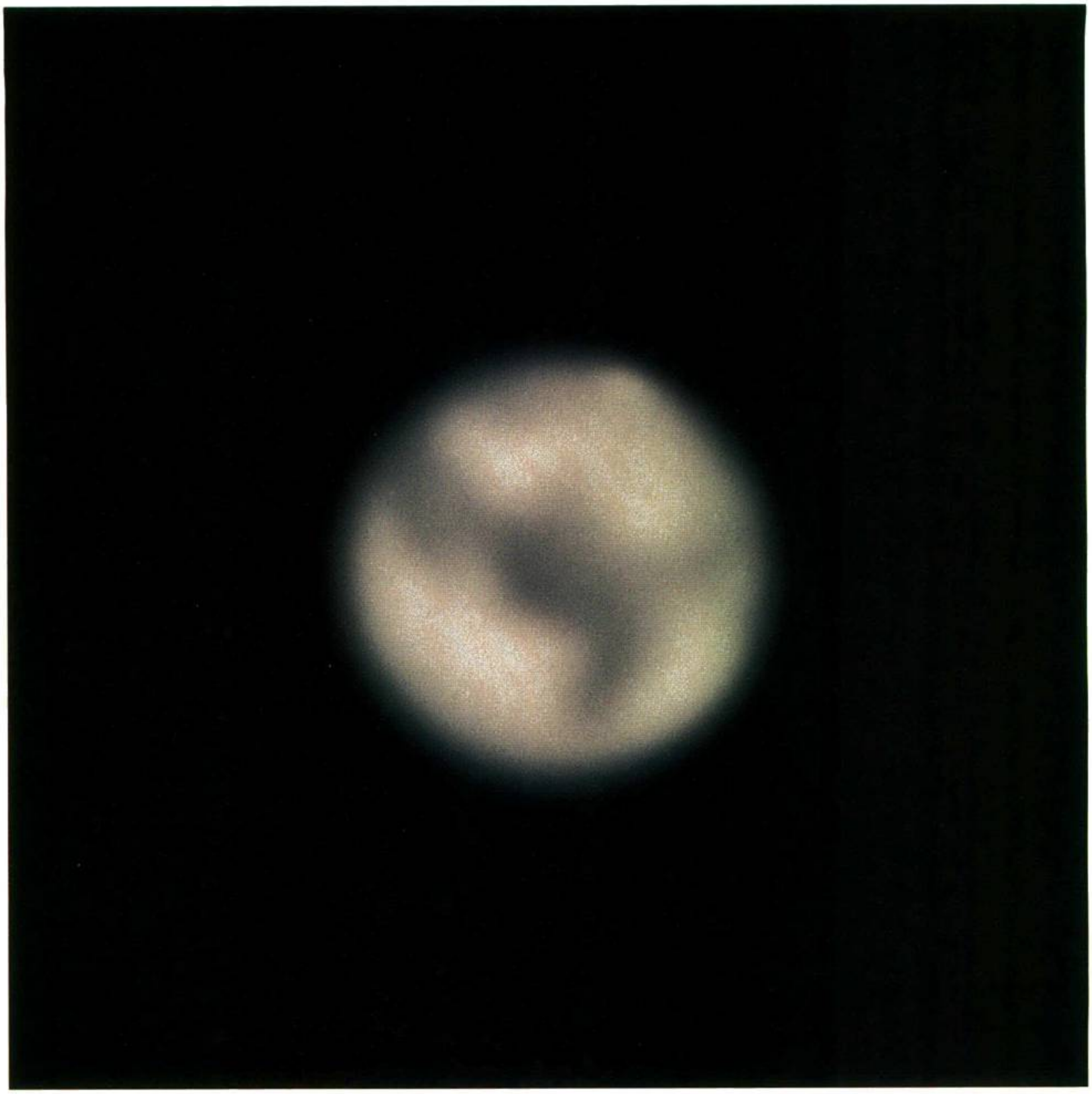
Planetary photography is a tricky business. Successful results depend on the right combination of film, exposure, and focal length of your telescope/camera system. Because planets appear so small, you need a focal ratio of between 100 and 200 to ensure that a planet's disk will be large enough to show detail. You also need a film fast enough to capture the faint light of a planet before the image trails on the film due to

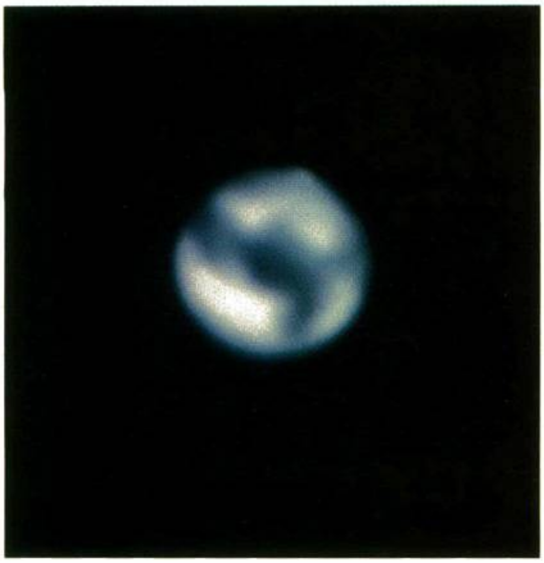


imperfect tracking or poor seeing. I recommend using a film between 100 and 200 ISO. This provides enough film speed for planets and gives you relatively fine film grain compared with still faster films. Follow the exposure guidelines in the table on page 69. Don't skimp on film. It's cheap compared with your time under the stars, so take several shots at each session. That increases the chances of getting some sharp photos during moments of good seeing, and it also provides you with multiple copies of similar shots — a key ingredient of slide duplication. Don't try to take multiple exposures on one film frame. To enhance your photos you'll need several similar images with the planet centered in each frame.

To enhance planetary shots, stack together several images in perfect register and rephotograph them using a slide duplicator. You can do this in several ways, with color or black and white film, negatives or slides. Whichever type of film you use, you must take the photos to be combined no more than several minutes apart. This will freeze the detail on the planet that would otherwise be blurred by rotation of the planet.

If you choose negatives, first you'll need to convert them into positives. Mount each negative in a slide holder, insert it into the slide duplicator, and photograph it using either Kodak Vericolor 5072 film, also known as SO 279 (for color negatives), or Kodak Technical Pan film (for black and white negatives). As you shoot these conversions, try to standardize as much of the process as possible. If the planet is not exactly centered on the original, center it in the new frame. This



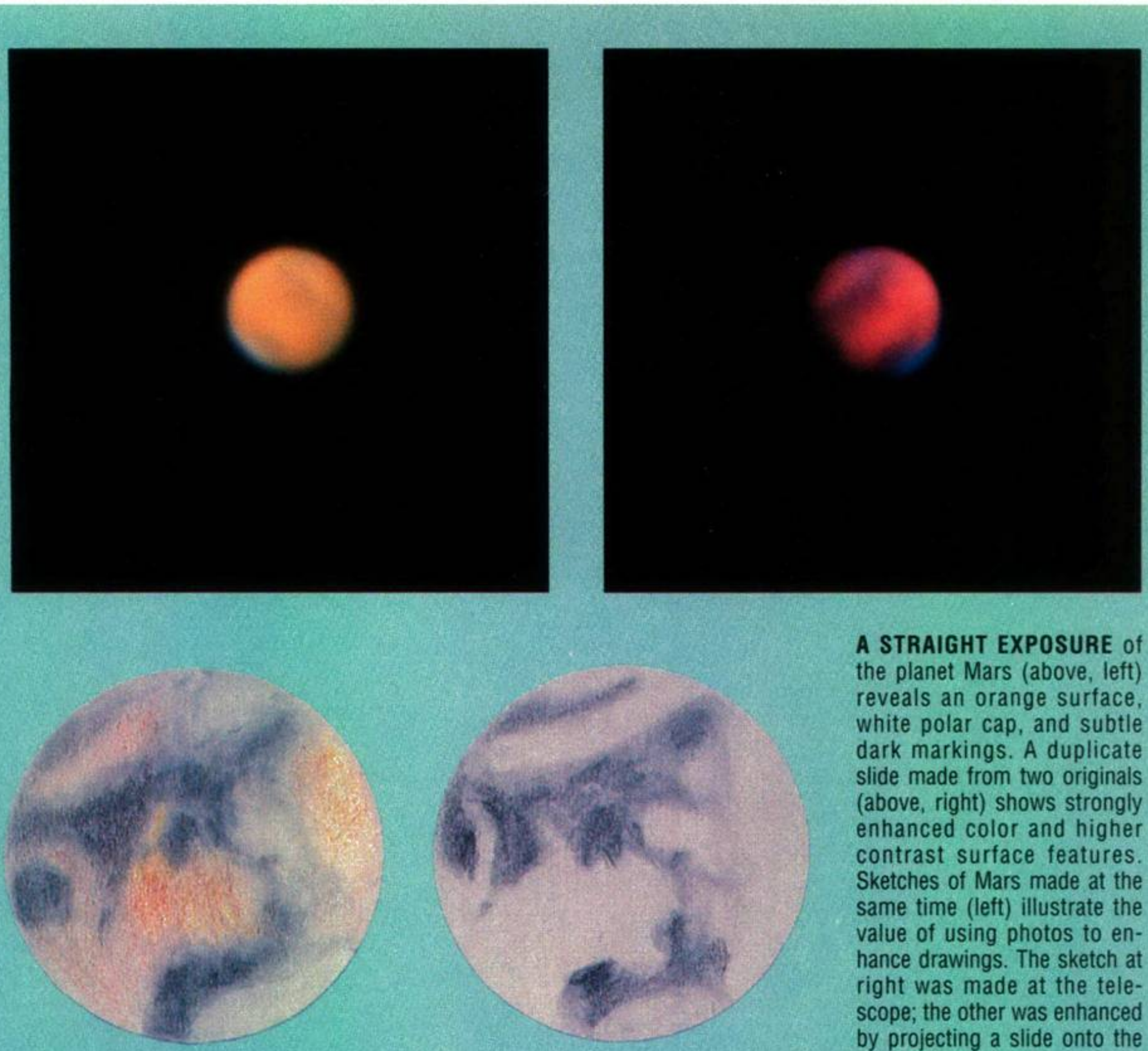


DUPLICATING TECHNIQUES offer markedly different results for planetary photos. Copying Mars onto Tech Pan film yields a sharp, snappy image (above). Copying two sandwiched negatives onto color film results in a high-contrast image with strong color (left).

makes superimposing the new positives in the next step much easier. When you're finished shooting the intermediate images, develop the film and mount the results in slide holders.

To obtain the final, high-contrast result, take two slides and sandwich them together into a single slide holder. Be sure they fall in exact register with each other. Then rephotograph them using the exposure times recommended in the table on page 71. I suggest using a fine-grained film like Fujichrome 100 for this purpose, even if you are shooting black and white positives. Because the sandwich is much darker than a single slide, exposures must be much longer than when you shoot single slides. Experimentation helps a great deal.

By duplicating two sandwiched slides you'll get increased image contrast. As I mentioned, low-contrast details often do not show up on planetary photos — you want high-contrast details that are easy to see. Sandwiching slides and copying them gives you a big boost in contrast. Clouds, subtle dark markings, and hazes barely visible in original images of Mars stand out clearly in



A STRAIGHT EXPOSURE of the planet Mars (above, left) reveals an orange surface, white polar cap, and subtle dark markings. A duplicate slide made from two originals (above, right) shows strongly enhanced color and higher contrast surface features. Sketches of Mars made at the same time (left) illustrate the value of using photos to enhance drawings. The sketch at right was made at the telescope; the other was enhanced by projecting a slide onto the disk and adding color.

EXPOSURE TIMES FOR PLANETARY PHOTOGRAPHY

Focal ratio	Venus	Mars	Jupiter	Saturn
100	1/60-1/15 sec.	1-2 sec.	1-2 sec.	4-5 sec.
200	1/30-1/8 sec.	2-3 sec.	2-4 sec.	6-10 sec.

Exposure times are given for films rated at 100 to 200 ISO.

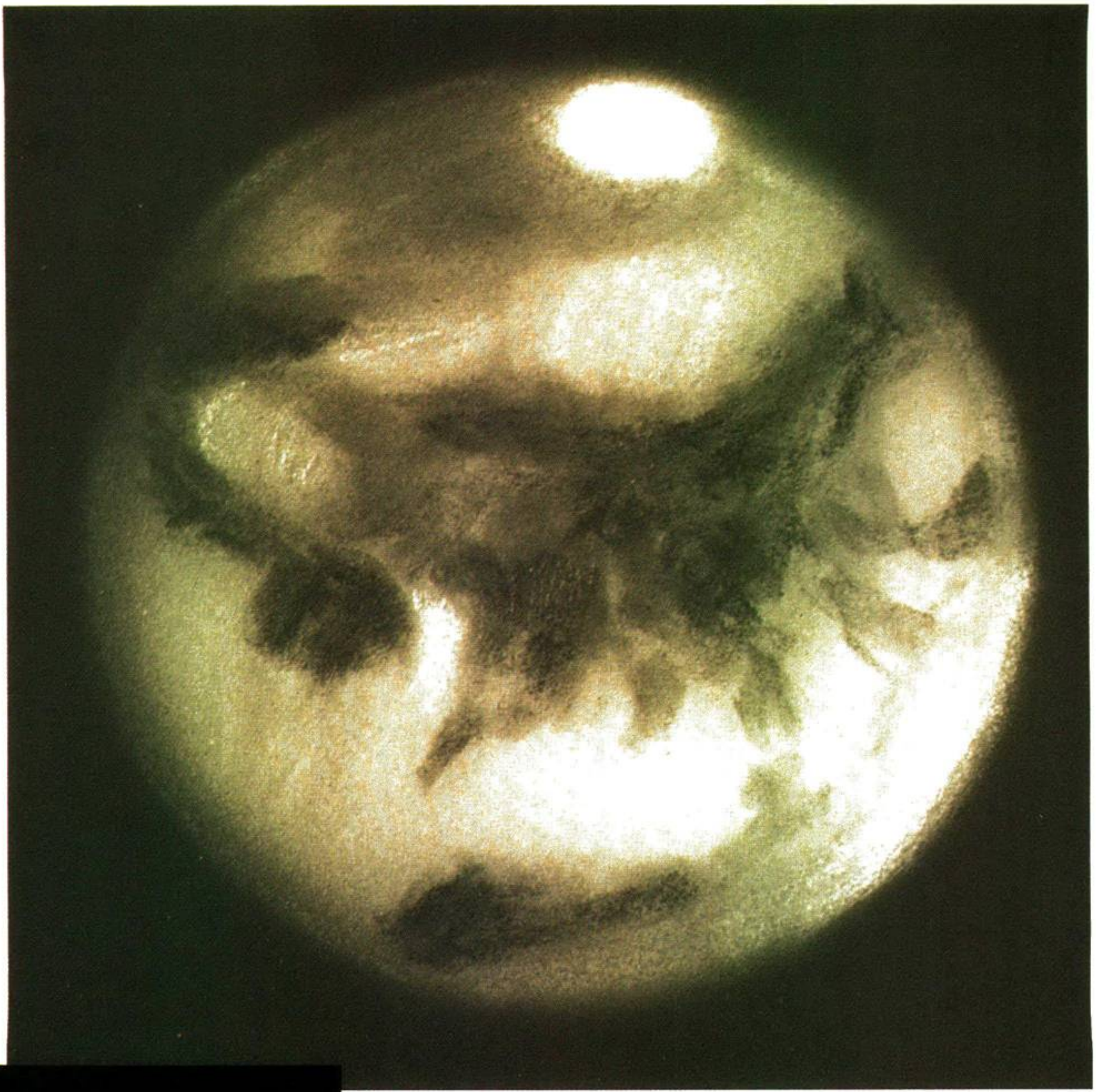
duplicates. Colors are more vivid in the dupes. You can also use color filters to accentuate various planetary features. A blue filter nicely brings out the bands and zones on Jupiter.

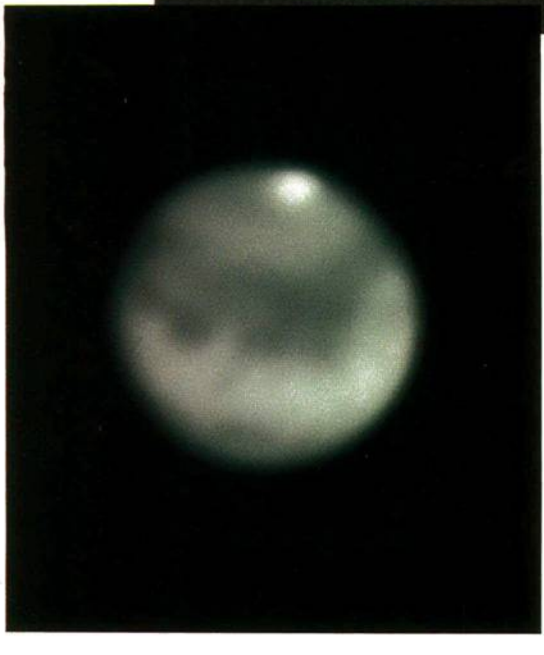
Visual Imaging: A New Approach

Photography holds no exclusive rights in the field of image enhancement. Planetary photography is limited in that it does not record detail as fine as the human eye can see. A sharp eye positioned at the eyepiece of a telescope can help record finer detail on a sketchpad. Planetary observers find drawing useful, especially for monitoring Mars, Jupiter, and Saturn for subtle changes that indicate activity in the cloud decks or in dust storms — activity too minute to be caught by the camera. Sketches and observations made by amateur astronomers have been used by professional astronomers to help model atmospheric activity on Mars and Jupiter.

Over the past few years I've developed a method that combines photographs and sketches to create accurate and detailed renditions of planetary activity. The method is simple. You can begin doing it on the next clear night. With steady atmospheric seeing, make several careful sketches of your favorite planet. Alternate each sketching session with a few photographs taken on the same night in fairly rapid succession. Be sure to keep accurate records of the times of each drawing and exposure.

When you make a sketch, begin by drawing the most prominent features first. Sketch cloud bands on Jupiter and Saturn, polar caps and dark regions on Mars. Place them as accurately as possible and then add progressively finer features as you



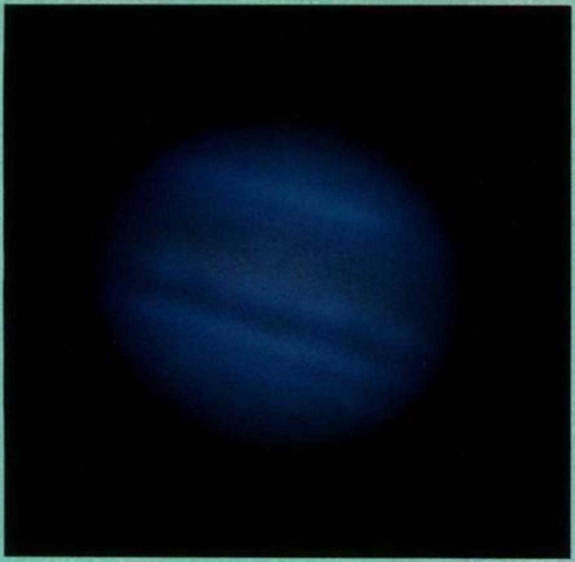


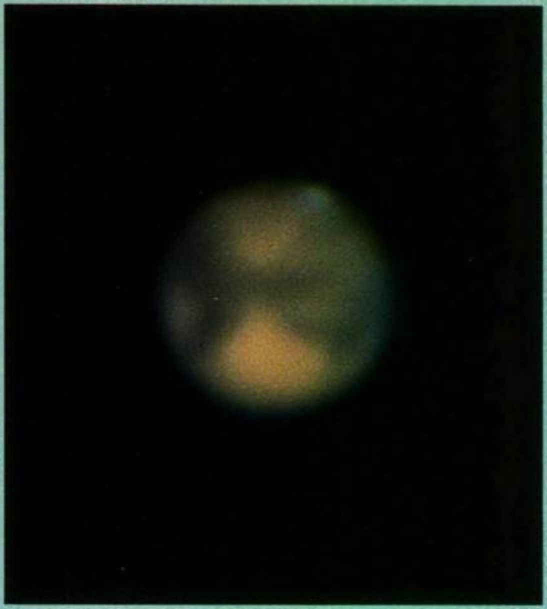
POSITIONAL ACCURACY is the biggest benefit of using slides to make enhanced sketches. The author produced the drawing of Mars above by projecting the original photo (left) onto the drawing and accurately rendering the positions of dark markings.

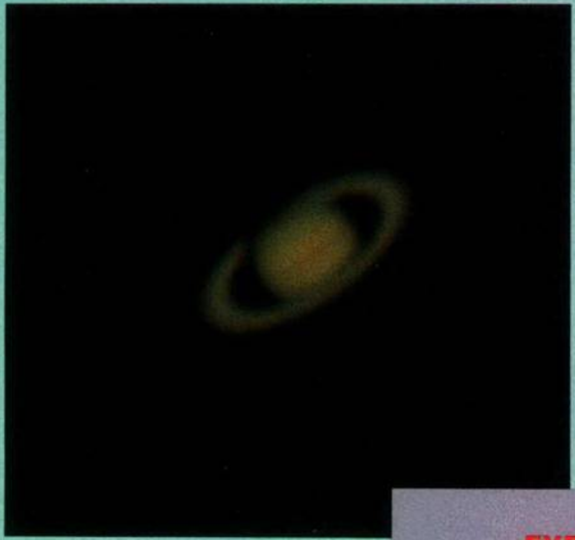
can see them during moments of good seeing. Be sure you finish each individual sketch within 10 or 15 minutes so the planet doesn't rotate appreciably during the sketch.

Standardize the procedure as much as you can. Either draw a circle of some size on the center of each piece of paper or use the approved form for individual planets from the Association of Lunar and Planetary Observers (ALPO). You can obtain these by sending a stamped, self-addressed envelope to ALPO, P.O. Box 143, Heber Springs, AR 72543. For photography, use the same focal ratio for each shot, bracket your exposures, and refocus each time. Record all information pertinent to your exposures.

After developing the film, pick the images that best correspond to the sketches. If you use black and white film, print the negatives on paper with a dull or semi-matte finish and enlarge the image to the same size as your drawing. Mount the dried print on art board and then transfer onto the print each of the subtle features recorded on your sketch but not visible in the photograph. You can use charcoal and white pencils for this and an artist's







THE BIG THREE PLANETS benefit most from slide duplicating and enhanced sketching. A duplicate shot through a light blue filter (above, left) enhances Jupiter's many equatorial belts, bands, and zones, as well as bright clouds associated with the planet's weather systems.

A WEALTH OF DETAIL pops out in this photo of Mars (above, right), a duplicate made from two originals sandwiched together. The duplication greatly enhanced the polar cap and limb clouds over Mare Erythraeum.

CLOUDTOP DETAIL is difficult to photograph on Saturn (left), yet a dark band shows plainly in this slide duplicate.

stump to blend in detail. The results will likely surprise you. You'll now have a hybrid photo-visual image with the major features accurately positioned and the fine detail enhanced and located in precisely the correct spot.

If you're using color slides, you need to alter the approach. Project the image onto white paper in a circle the same size and adjacent to your drawing. Orient the two images so they are in register and then retrace the main features from the photograph onto the paper. As with the other method, this gives you accurately positioned major features and you can now transfer fine details from your original sketch onto the paper. You'll then have a finished, enhanced drawing.

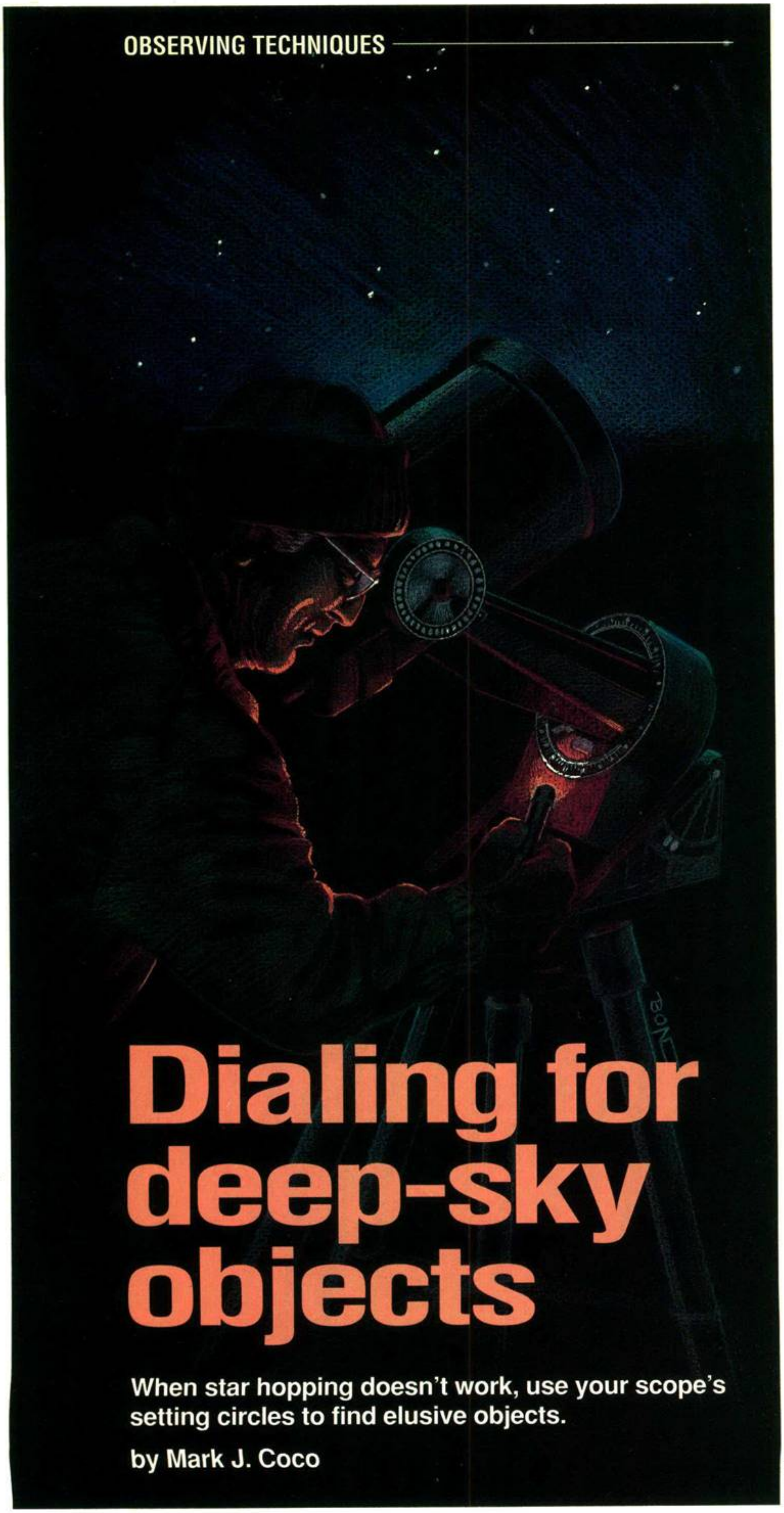
EXPOSURE TIMES FOR SLIDE DUPLICATION

Duplicating Film	Single slide	Sandwich	Light	Exposure
Fuji 100	X	—	blue sky	1/2-1 sec.
Fuji 100	—	X	blue sky	1-4+ sec.
Fuji 100	X	—	photo-flood	1/2-1 sec.
Fuji 100	—	X	photo-flood	1-4+ sec.
Tech Pan	X	—	250 watt	1/8-1/30 sec.
Tech Pan	—	X	250 watt	1/4-1/15 sec.

Use a 250-watt EGA (3200K) or equivalent, or a clear afternoon sky away from the Sun and an ultraviolet absorption filter, for illuminating color film.

This technique buys you a lot of confidence. The next time you pick up a batch of slides from the processor you'll have a great feeling of accomplishment. If the slides lack a little contrast, so what. You now have two great ways of enhancing your planetary shots, giving them the zing that will impress Aunt Edna and the kids at the next family slide show. What more could you ask for? □

Klaus R. Brasch is a biology professor at California State University in San Bernardino. He is also a member of the Association of Lunar and Planetary Observers.



Dialing for deep-sky objects

When star hopping doesn't work, use your scope's setting circles to find elusive objects.

by Mark J. Coco

Bruce Bond

"Darn! M76 should be right in the eyepiece. I know it's north of the bright star Almach, but I can't find it. There's got to be a way to find it."

There is: Use those mysterious circles on your mount. Hopping from bright star to bright star is an easy way to find some deep-sky objects. But when the object you want to observe doesn't have a convenient path of bright stars leading to it, you can use your scope's setting circles to guide you to the object.

All you need is a German equatorial or fork mount that is polar aligned and has setting circles. You don't need a clock drive, although that makes finding objects a little easier. Using either the direct indexing or offset methods described below, your circles can get you close enough to an object's position that a quick search of the region will reveal the object. To see how both of these methods work, let's first look at how astronomers map the sky.

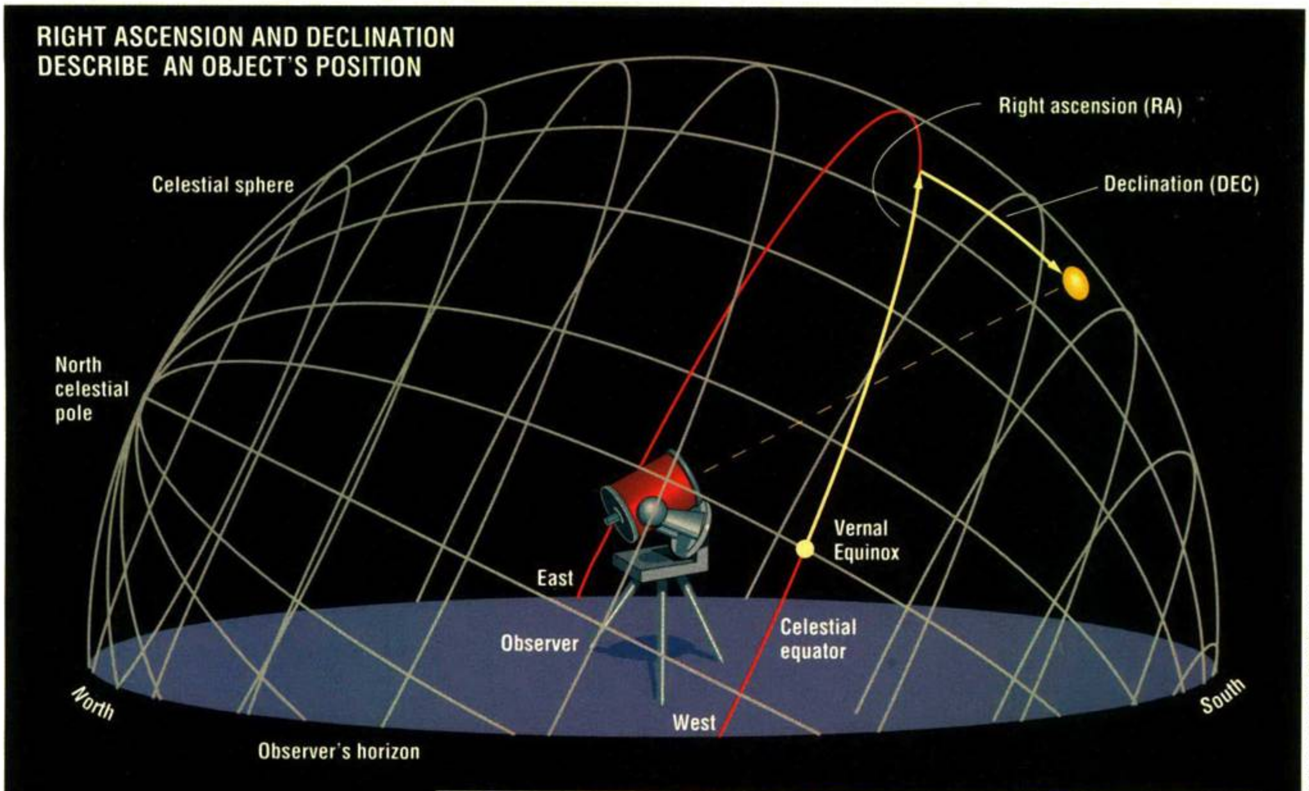
Earth and Sky Coordinates

All stars appear fixed on a distant sphere called the celestial sphere. Earth is small compared to the size of the celestial sphere, so all observers on Earth are effectively located at the center of the sphere. To map the positions of stars and other objects on the celestial sphere, astronomers use several different coordinate systems. The one most useful for pointing telescopes is the equatorial system.

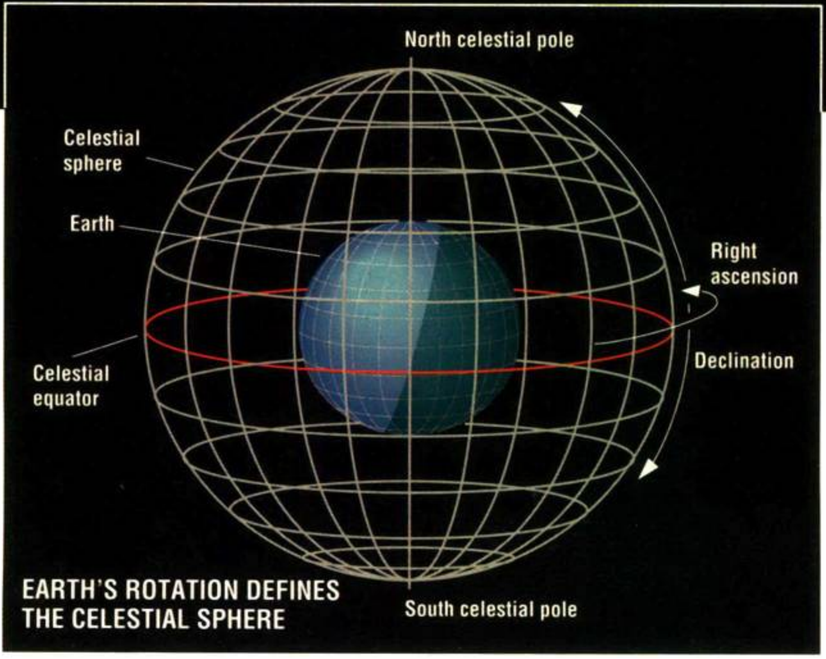
The equatorial system is based upon Earth's latitude and longitude system. Extending Earth's rotational poles out to the celestial sphere defines the north and south celestial poles. Earth's equator extended out to the celestial sphere defines the celestial equator, which divides the sky into two domes or hemispheres.

On Earth, the angular measure of a city from the equator is its latitude. Astronomers call the equivalent "celestial latitude" declination (abbreviated Dec). Ninety degrees of declination separate the celestial poles from the celestial equator. The celestial equator has a declination of 0°, declinations in the northern hemisphere have positive numbers, and declinations in the southern hemisphere have negative numbers. Because 1° covers a large amount of sky, astronomers divide the degree into 60 minutes (abbreviated ') and each minute into 60 seconds (abbreviated ").

Where the celestial pole and the celestial equator appear in the sky depends on your latitude. The point directly overhead, called the zenith,


RIGHT ASCENSION AND DECLINATION DESCRIBE AN OBJECT'S POSITION
Celestial sphere
Right ascension (RA)
Declination (DEC)
North celestial pole
Vernal Equinox
East
Observer
Celestial equator
North
West
South
Observer's horizon

DECLINATION MEASURES an object's position above or below the celestial equator. Right ascension is the angular distance east from the vernal equinox.


North celestial pole
Celestial sphere
Earth
Right ascension
Declination
Celestial equator
EARTH'S ROTATION DEFINES THE CELESTIAL SPHERE
South celestial pole

EXTENDING EARTH'S POLES and equator out to the celestial sphere fixes the celestial poles and equator.

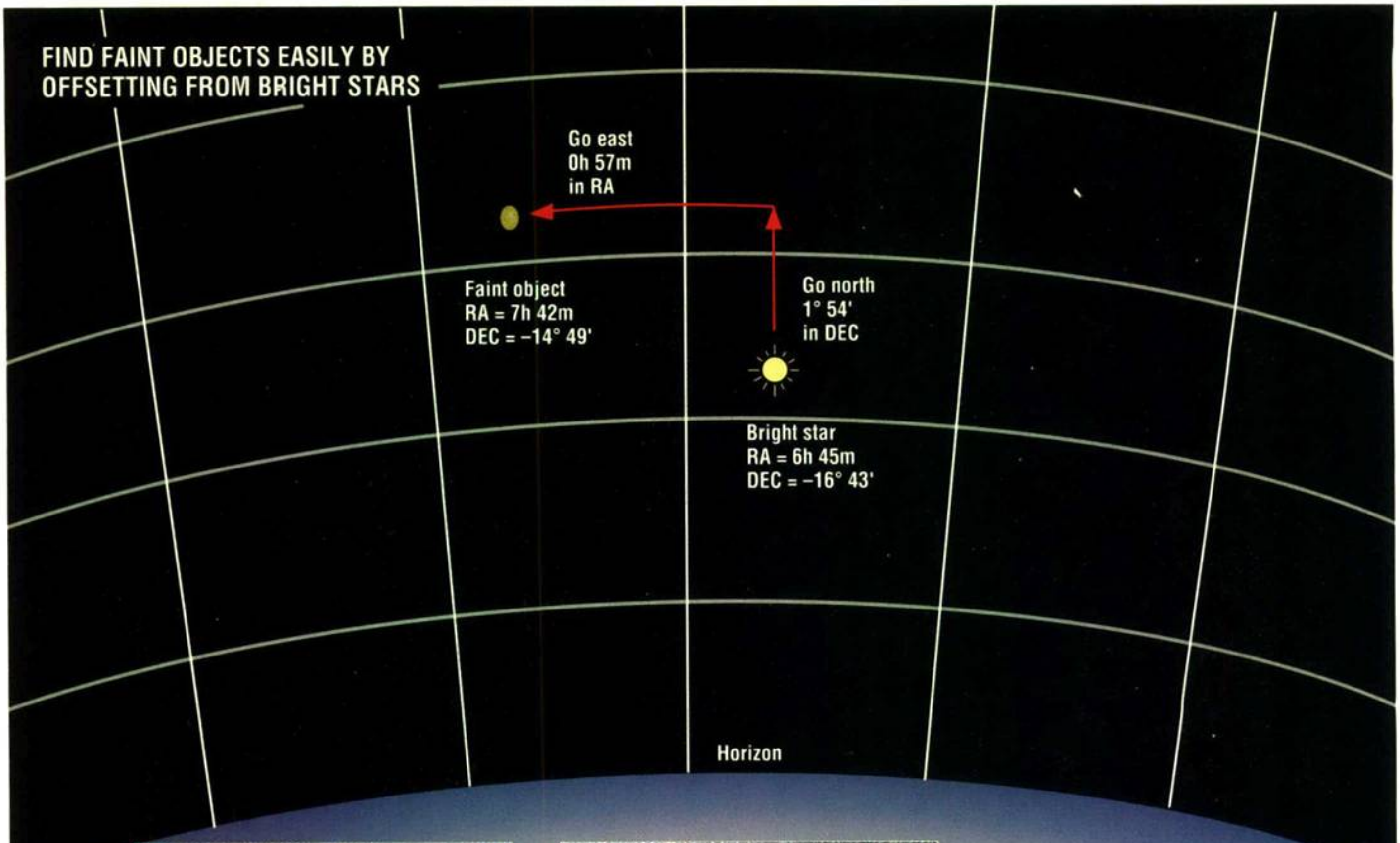
ASTRONOMY: all illustrations by Phil Kirchmeier

appears at a declination equal to your latitude. The celestial equator lies an angular distance equal to your latitude from the zenith. The angular distance of the celestial pole above the horizon — the true horizon, not one cluttered with trees, hills, or buildings — is also the same as your latitude.

The second celestial coordinate, right ascension, mimics Earth's longitude. Tracing Earth's longitude lines out to the celestial sphere yields lines of right ascension (abbreviated RA). Because objects rise and set at different times, astronomers use hours to measure right ascension. Twenty-four hour lines mark right ascension on the celestial sphere, with each line marking one hour. One hour of right ascension covers a lot of sky (up to 15° at the equator), so astronomers divide each hour into 60 minutes (abbreviated m) and each minute into 60 seconds (abbreviated s). Don't confuse minutes and seconds of right ascension with minutes and seconds of declination. Four minutes of right ascension at the equator covers 1 degree of sky or the equivalent of 60 minutes of declination. At higher declinations, the same four minutes of right ascension cover less sky because lines of right ascension lie closer together near the poles compared with near the equator.

While the celestial equator and poles provide a natural starting place to measure declination, right ascension can start anywhere. Earth longitudes have this same arbitrariness. By international convention, Earth longitudes start at Greenwich, England, with positive longitudes east of Greenwich and negative longitudes west. Right ascension 0h 0m 0s occurs at the vernal equinox, the point where the Sun crosses the celestial equator heading north on its apparent path annually through the sky. Astronomers measure other right ascensions eastward from this point up to a maximum of 23h 59m 59s.

Your telescope's equatorial or fork mount has two axes. One axis moves the scope in declination and the other, sometimes called the polar axis, moves it in right ascension.



USE A BRIGHT STAR TO FIND elusive deep-sky objects. Center your scope on the star and offset in RA and Dec to the faint object.

ASTRONOMY: both photos by Darla Gawelski

RIGHT ASCENSION INCREASES to the east. This circle, which has marks every 10 minutes, reads 6h 45m.

DECLINATION INCREASES to the north. This circle has divisions every 2° and reads −17°.

Each axis has a setting circle. The Dec circle has divisions every one or two degrees and ranges from −90° to +90°. The RA circle has 24 divisions marking every hour and additional divisions marking every 5 or 10 minutes.

If the RA circle on your scope has divisions reading 0 to 6 and back to 0, you have an hour angle circle instead of a RA circle. A circle divided into 24 hours can also read hour angle and not right ascension. If you move your scope to the east, the number on the circle should increase. If it doesn't, you have an hour angle circle. Don't worry. You can use an hour angle circle to find deep-sky objects.

Using Your Setting Circles

Backyard astronomers use setting circles in two ways. In offsetting, you use the circles to move from a bright star to the object of interest. You can use this technique with any scope that has setting circles. With direct indexing, you use the circles to dial in an object's coordinates directly. In order for you to use this technique, your scope must have an RA circle and not an hour angle circle.

Both of these techniques require that you polar align your scope. Good polar alignment is needed for offsetting your scope; precise polar alignment is needed for direct use of the circles. (See "Polar Aligning Your Telescope" in the May 1992 ASTRONOMY). If you plan to use offsets to find deep-sky objects, skip to the section entitled "Offsetting to Objects." If you plan to use direct indexing, you need to calibrate your setting circles.

Polar alignment automatically calibrates the Dec setting circle. The reason for this is that the lines of declination remain constant in the sky. So once you have the scope aligned to the pole, the circle should always be calibrated. If the circle has slipped, it is easy to recalibrate. With your scope polar aligned and the scope pointed at the pole, the Dec circle should read 90° degrees — +90° for observers in Earth's Northern Hemisphere and −90° for those in the Southern Hemisphere. If it doesn't read 90°, loosen the screw holding the circle to the declination axis and rotate the circle until it reads 90°. If your Dec circle doesn't have a screw but is glued to the axis instead, bend the indicator slightly so the circle

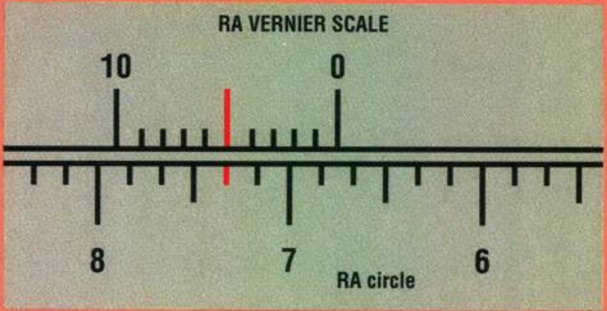
Reading Vernier Scales

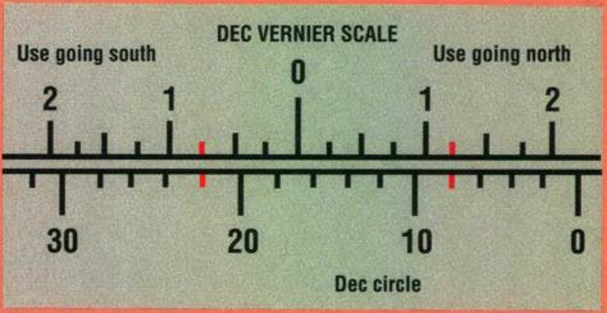
Vernier scales enable you to read setting circles more accurately. Typically you can determine an object's position to within 1 minute in RA and 15 arcminutes in Dec using verniers.

The zero mark on the RA vernier is the RA indicator. If the mark lines up exactly with one on the circle, then the RA is exactly the number on the circle. Commonly the indicator points between two marks on the circle. In the example at right (the vernier is compressed for clarity), the indicator points between 6h 40m and 6h 50m. So the base RA is 6h 40m. Determine the exact number of minutes by finding which vernier mark lines up with a mark on the circle and add this number to the base RA. In the example, the 5-minute mark lines up with 7h 20m. Add 5 minutes to 6h 40m to get 6h 45m.

Dec circles have two verniers, one for going south and one for going north. If the zero indicator lines up with a mark on the Dec circle, then the Dec is exactly the number on the circle. In the example, the indicator lies between –16° and –18°. Going north, the southernmost number (–18°) is your base Dec. Using the right vernier, the 1° 15' mark lines up with 8° on the circle. You add this number to the base Dec. So in the example, –18° 00' plus 1° 15' yields a Dec of –16° 45'.

Going south, use the left vernier to obtain the Dec. In the example, the 45' mark lines up with –22°. Subtract this number from the northernmost Dec near the zero indicator. So in the example, –16° minus 45' yields a Dec of –16° 45'.





reads 90°, or break the glue bond, carefully set the circle, and reglue it.

If you plan to use direct indexing and you have an RA circle and a clock drive, check to see if your circle is driven. Point your scope east, note the right ascension marked by the indicator, and turn on the clock drive. Come back in a half-hour or so and read the RA circle again. If the circle reads the same as it did initially, your circle is driven. If the circle reads a lower right ascension, then your circle is not driven. Most Schmidt-Cassegrain telescopes have driven circles, but many German equatorial mounts do not.

For driven circles, calibrating the RA circle need be done only once at the beginning of the night. For non-driven circles, you need to calibrate before you search for each object. Calibration of the RA circle is necessary because the stars and the vernal equinox move across the sky due to Earth's rotation and orbital motion around the Sun. You can keep track of the motion of the vernal equinox using a special time system called sidereal time, but a simpler way exists.

Find a bright star in your scope and, if you have one, turn on the scope's clock drive. Look up the star's right ascension in a star catalog and then simply turn the RA circle until the indicator points to this number. Your RA circle is now calibrated.

Direct Indexing

Before you start observing, prepare a list of objects you wish to find, including each object's coordinates and the coordinates of one or more bright stars for RA circle calibration. Don't use a star chart to obtain the objects' coordinates; it provides only an approximate set of coordinates. Use a catalog or other reference book to look up the coordinates.

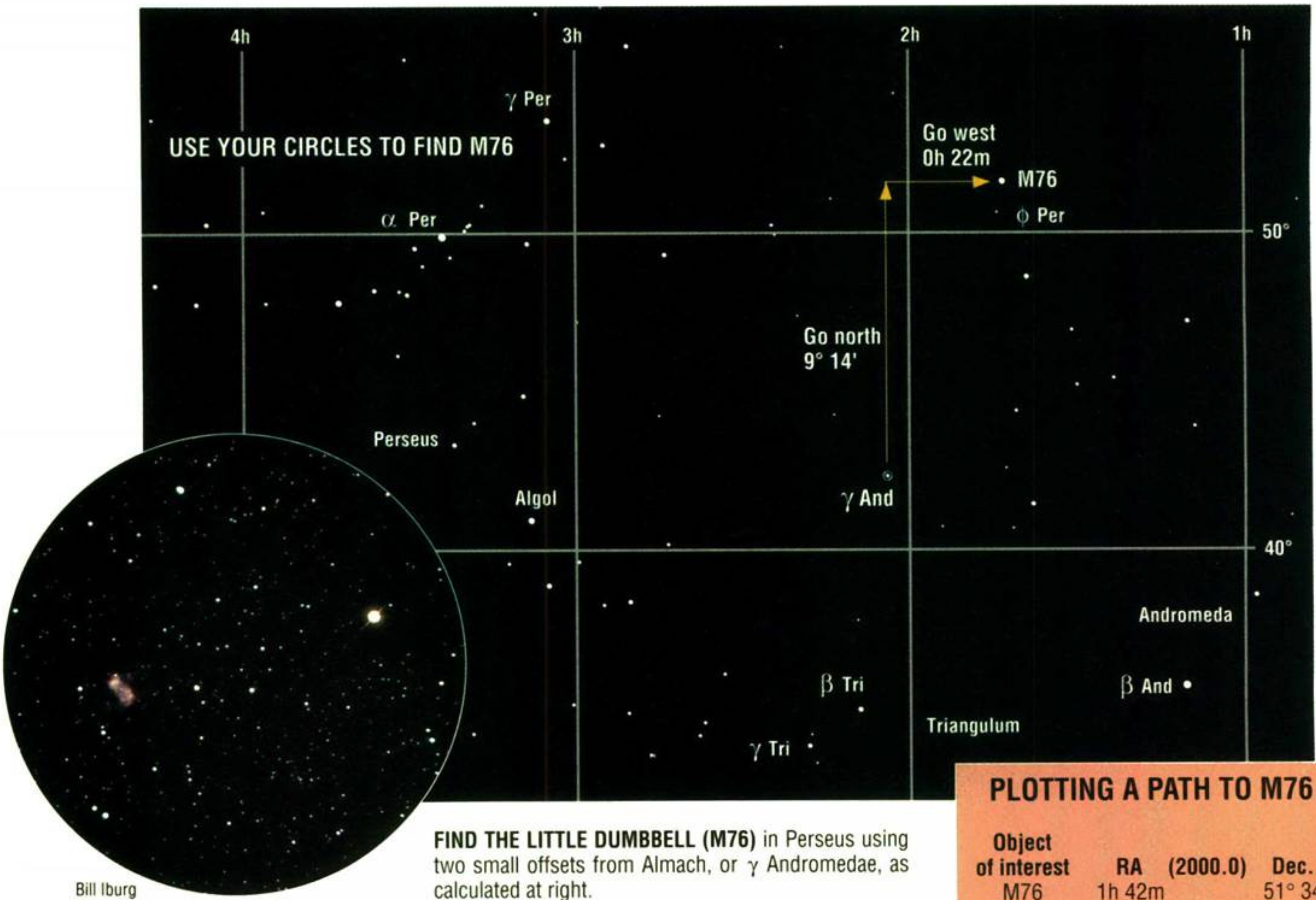
Armed with the correct coordinates, go to the telescope and calibrate the RA circle. Then move your scope until the circles indicate the coordinates of the object you wish to find. An easy object to find is the Beehive cluster (M44) in Cancer at right ascension 8h 40m and declination +20° 00'. The object should appear in the finder.

To move to the next object, simply move the scope to the object's coordinates if you have a driven RA circle. If not, you don't have to recalibrate the RA circle using a bright star. Simply rotate the RA circle to the present object's right ascension before you move the scope to the next object.

In a perfect world, moving the telescope until the circles indicate the proper coordinates should put the object right in the center of the field of your telescope. But this doesn't always occur. Several factors influence the accuracy of your setting circles. One is polar alignment; inaccurate alignment throws off the reading of your setting circles. While setting up, take a little extra time to align your polar axis as precisely as possible.

A second factor is the epoch of coordinates you use for calibrating the RA circle and the coordinates of the objects sought. Precession, a slight wobble of Earth's rotational axis, causes the positions of stars to shift. Over a period of 50 years, precession can cause an object to shift by as much as 16' in declination and 3 to 15 minutes in right ascension. So astronomers compile catalogs of star and object positions for different dates or epochs. Most catalogs now printed use epoch 2000.0 coordinates, but older catalogs may use 1950.0 or even 1900.0 coordinates. Which epoch you use doesn't generally matter as long as you use coordinates from the same epoch for both RA calibration and the target object.

Using 1950.0 coordinates for a bright star to calibrate the RA circle, but 2000.0 coordinates for a deep-sky object can cause you to miss the object. If you need to use different epochs, you can find tables — and equations, if you prefer them — to convert coordinates from one epoch



FIND THE LITTLE DUMBBELL (M76) in Perseus using two small offsets from Almach, or γ Andromedae, as calculated at right.

Bill Iburg

PLOTTING A PATH TO M76

Object of interest	**RA (2000.0)**	**Dec.**
M76	1h 42m	51° 34'
Nearest bright star	**RA (2000.0)**	**Dec.**
γ And	2h 04m	42° 20'

Subtract bright star position from object's position to obtain offsets.

Offsets	–0h 22m	9° 14'
Direction	go west	go north

to the other in reference books such as the *Observer's Handbook*.

Yet another factor that affects the accuracy of your setting circle readings is the circles themselves. Most Dec circles have a marker every one or two degrees. RA circles typically have divisions every 10 minutes. Finer divisions are useful for finding faint objects not easily seen in a finderscope. Some manufacturers provide vernier scales, a finely divided scale that augments the setting circles, to enable you to obtain more accurate readings. See Reading Vernier Scales on the previous page.

Offsetting to Objects

Setting circles can still help you find faint deep-sky objects even if your scope has only an hour angle circle or if you don't want to bother with a precise polar alignment. A clock drive makes offsetting easier but it's not necessary.

Instead of calibrating the RA circle as you must do for direct indexing, you use differences in right ascension and declination between the object and a bright, nearby star. Suppose you want to find the Little Dumbbell (M76), a faint 11th-magnitude planetary nebula in Perseus. Its coordinates are right ascension 1h 42m and declination +51° 34'. Use a star atlas to find a bright star nearby. (Remember to get its position from a catalog, not from the star atlas.) The star should be easily visible in your finderscope and close to the object so errors in the polar alignment don't affect the offset. Also, if you don't have a clock drive, a nearby star prevents the object from drifting much while you move the scope from the star to the object.

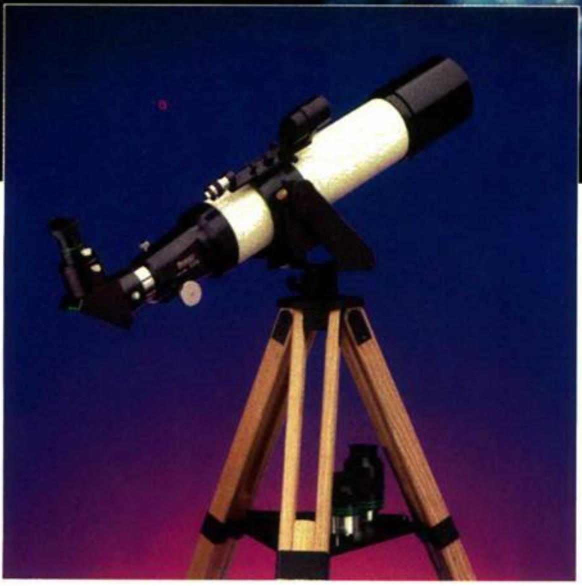
Many bright stars lie near M76. The closest is γ Andromedae, a 2.3-magnitude star that is also called Almach. It lies at right ascension 2h 04m and declination +42° 20'. The difference in Almach's and M76's positions is 0h 22m in right ascension and 9° 14' in declination. You should compute these offsets before you set your scope to Almach.

Find Almach and center it in your scope. Note the readings of the setting circles. Move the scope west in right ascension 22 minutes and then north 9° 14'. You may need to round these numbers slightly, depending upon the divisions on your circles, say to 20 minutes in RA and 9° 15' in Dec. This object may not be visible in your finder, so sweep the region carefully with a low-power eyepiece in your telescope.

Whether you use offsets or direct indexing, setting circles can help you find objects too faint to be seen in you finderscope or objects that don't have good star-hopping paths. Learning to use your circles can open a new realm of objects for you to observe. And while you don't need to use setting circles to enjoy the night sky, they can make it easier to find some elusive objects. ☐

Mark J. Coco is a technical writer and amateur astronomer living in Southern California.

VISIT NATURE'S HEAVENLY MUSEUM.



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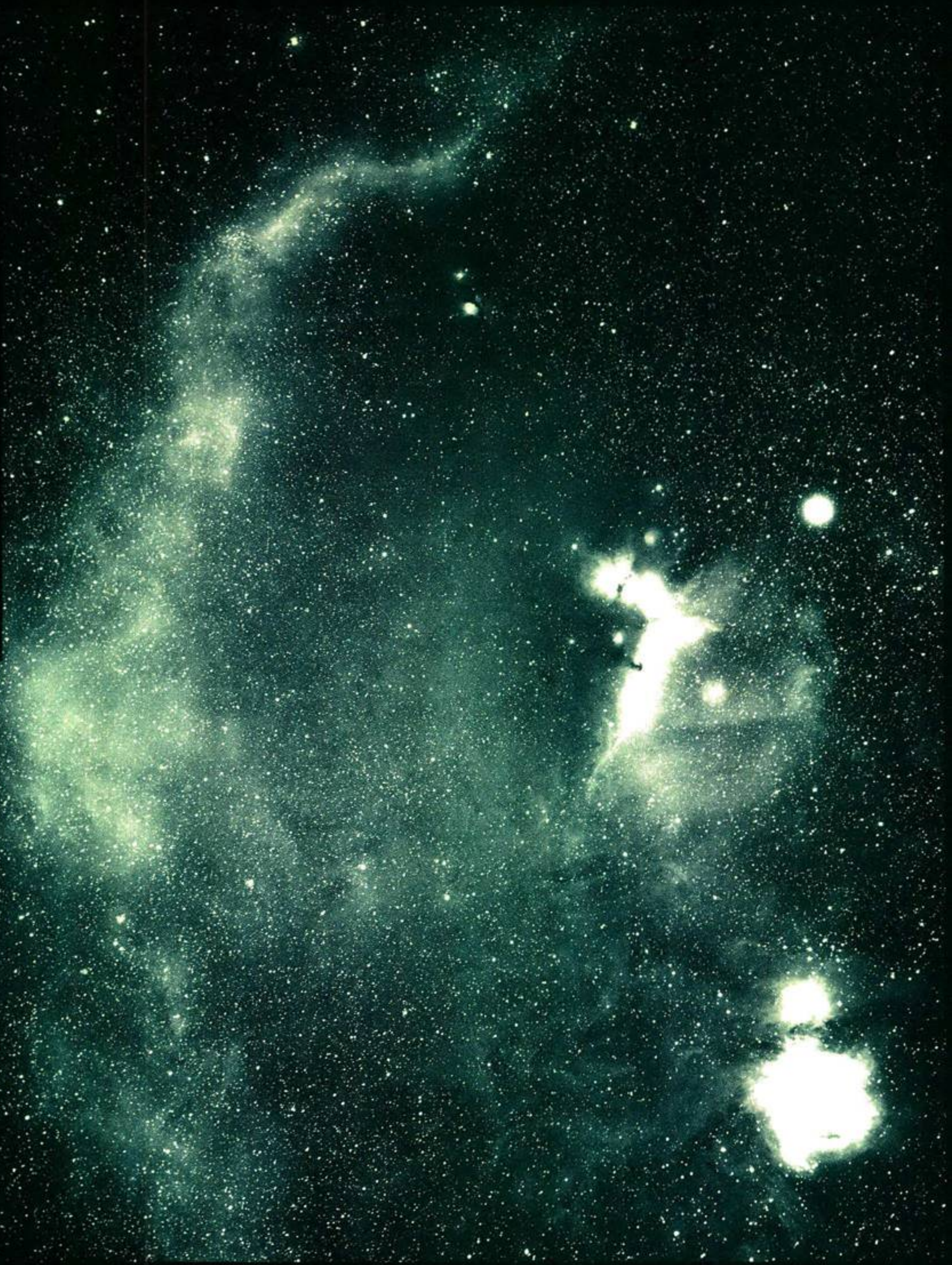
ORION

THE ORION NEBULA
Michael Stecker

THE BRIGHTEST DEEP-SKY object in Orion is the Orion Nebula (above). The constellation is awash in nebulosity as evidenced in this deep exposure of the central part of the constellation.



CENTRAL ORION
Michael Stecker

THE BACKYARD ASTRONOMER

Winter's Nebulae and Star Clusters

The constellations Orion, Taurus, Canis Major, and Perseus are packed with star clusters and nebulae — and a few galaxies, too.

by David J. Eicher

DARK COMETARY GLOBULE
Chuck Vaughn

LAMBDA ORIONIS BUBBLE
Yerkes Observatory

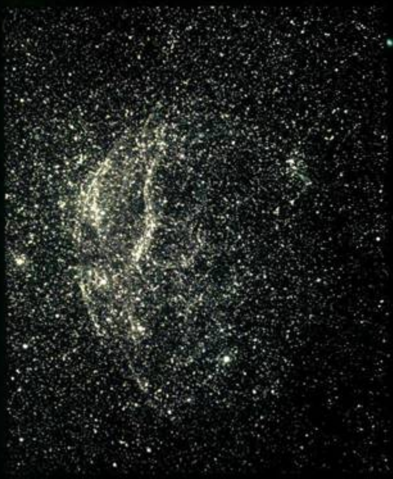
REFLECTION NEBULA M78
Jack B. Marling

THE HORSEHEAD NEBULA
Michael Stecker

It happens every time you go out on a dark winter night. It's cold outside. You bundle up and brave the chill. You stretch (trying not to think about your hard day at work), shiver from the cold, and look up. There they are — the most brilliant, recognizable star groups in the sky. The boxy frame of Orion. The big, loose star clusters of Taurus. Canis Major's dazzling Sirius, the brightest star in the sky. And the arc-shaped form of Perseus, winding its way up toward the pole. After a few minutes of getting your eyes used to the dark, you're rewarded by these great spectacles of nature.

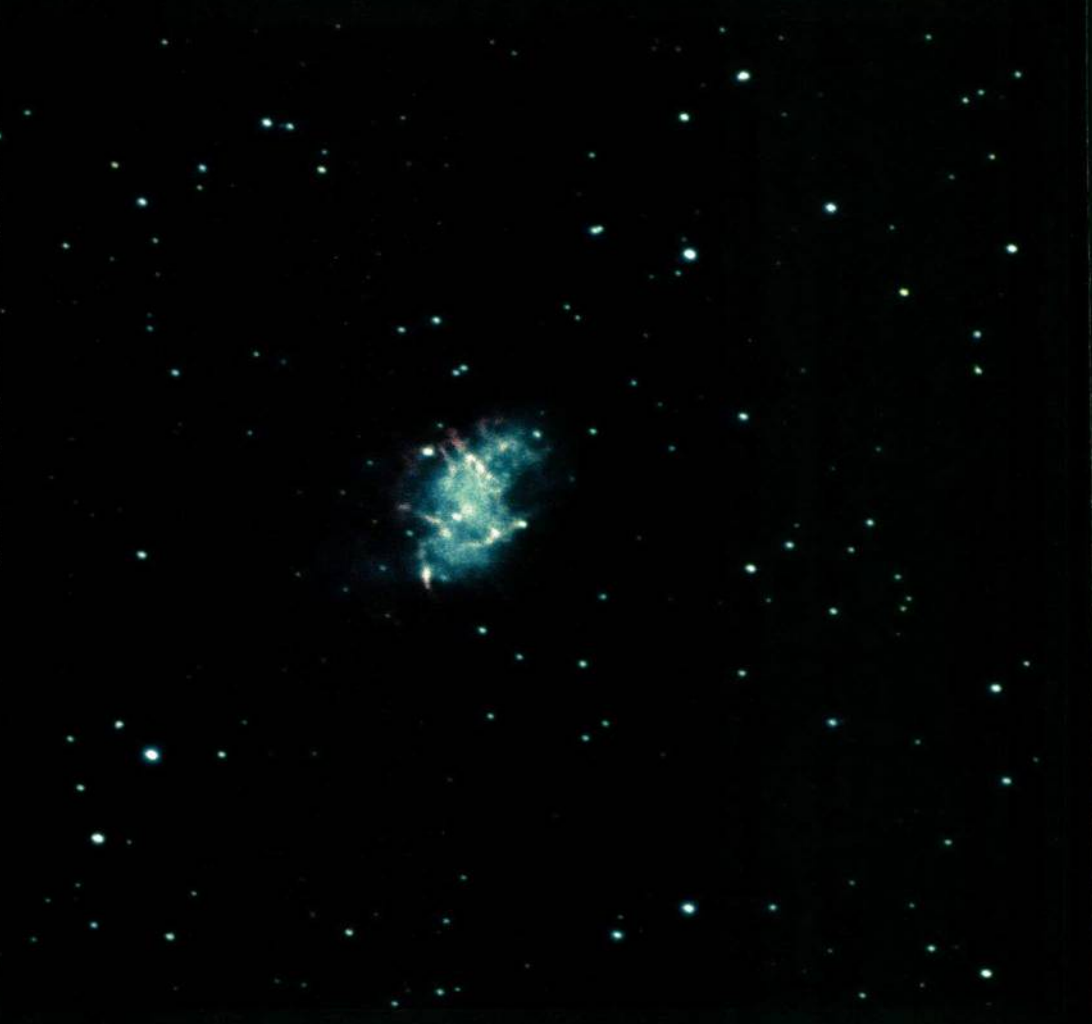
Every backyard astronomer knows the winter evening sky as poetry for human eyes. Yet as magnificent as the naked-eye view is, something with a deeper meaning lies beyond it. A hidden world visible in binoculars and telescopes awaits you — star clusters and nebulae and even a few galaxies.

To begin your exploration, start with Orion the Hunter. Seven stars comprise the big frame of Orion — from his shoulders, marked by Betelgeuse and Bellatrix, to his knees, represented by Rigel and Saiph. Orion's Belt lies in the center of this frame, the belt stars — Mintaka, Alnilam, and Alnitak — visible to the naked eye. Midway between Orion's Belt and his knees you'll



S147 IN TAURUS
Michael Stecker and
James R. Foster

ONE OF THE FAINTEST deep-sky objects in Taurus, S147 (above) is an ancient bubble blown off by a supernova explosion. The Crab Nebula, located nearby, is another supernova remnant.



THE CRAB NEBULA
Ronald E. Royer

HIND'S VARIABLE NEBULA
Martin C. Germano

PLANETARY NEBULA NGC 1514
Chuck Vaughn

find the Sword of Orion, a north-south line of three stars. Take a close look at the middle star in the Sword. You'll see that it appears fuzzy even to the naked eye. Not a star at all, this is the **Orion Nebula** (M42, NGC 1976), a gas cloud surrounding a cluster of hot stars. Binoculars show the Orion Nebula as a fuzzy cloud of greenish light surrounding a knot of white stars. South of the brightest part you'll see faint streamers of nebulosity arcing away from the central nebula. Generally these are visible only in a 4-inch or larger scope.

Long-exposure photographs of Orion show that the Orion Nebula is merely a hot spot in a giant cloud of faintly glowing light that engulfs the entire constellation. Whereas the Orion Nebula shines like a fluorescent bulb and is a stellar nursery — a cloud of gas condensing into new stars — **M78** (NGC 2068), just northeast of Alnitak (the easternmost belt star), consists of small dust grains and glows by light reflected from a nearby star. Just south of Alnitak, you can see the **Horsehead Nebula** (B33). A dark nebula of dust backlit by a thin strip of glowing gas, the Horsehead Nebula typically requires at least a 10-inch telescope to be seen. On an extremely dark night you may use binoculars to view the **Lambda Orionis Bubble**, a huge

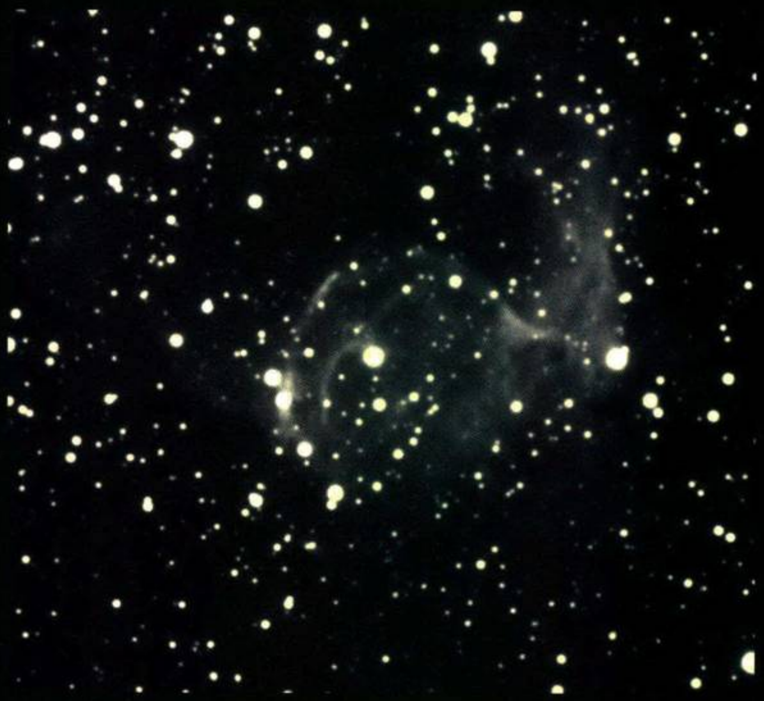
CANIS MAJOR

OPEN CLUSTER M41
Thomas L. Dessert

STAR CLUSTER M41 is one of the prettiest in the sky. The second-brightest star cluster in Canis Major is NGC 2362.

OPEN CLUSTER
NGC 2362
Chris Schur

EMISSION NEBULA IC 2177
Robert C. Bickel



COSMIC BUBBLE NGC 2359
Kim Zussman

(4° across), faint disk of nebulosity surrounding the star Meissa, or Lambda Orionis. Although it is faint, the bubble is visible if you slowly sweep across the region with binoculars and note the change in background skyglow. Hot stars, including Meissa, formed the bubble with their intense radiation and fierce stellar winds.

Orion holds no exclusive patent on winter sky wonders. Taurus the Bull, its neighbor to the north, offers a variety of easy and challenging telescopic sights. Unaided eyes nicely show the two most prominent features of the constellation, the **Hyades** and **Pleiades** (M45) star clusters. East of the Hyades, just northwest of the star Zeta Tauri, you'll find the **Crab Nebula** (M1, NGC 1952). A telescope shows the fuzzy glow that resulted from a supernova explosion about 940 years ago. The slowly expanding shell of gas moves outward at high speed, slowly diffusing into the space surrounding the blown-out star. Just a few degrees north of the Crab you'll find **Simeis 147**, the much larger, much fainter remains of an ancient supernova. This object is so old and so spread out that it may be visible only in photographs. More visible treasures in Taurus include the planetary nebula **NGC 1514**, located 8° northeast of the Pleiades, and the unusual object

PERSEUS

NGC 1491
Martin C. Germano

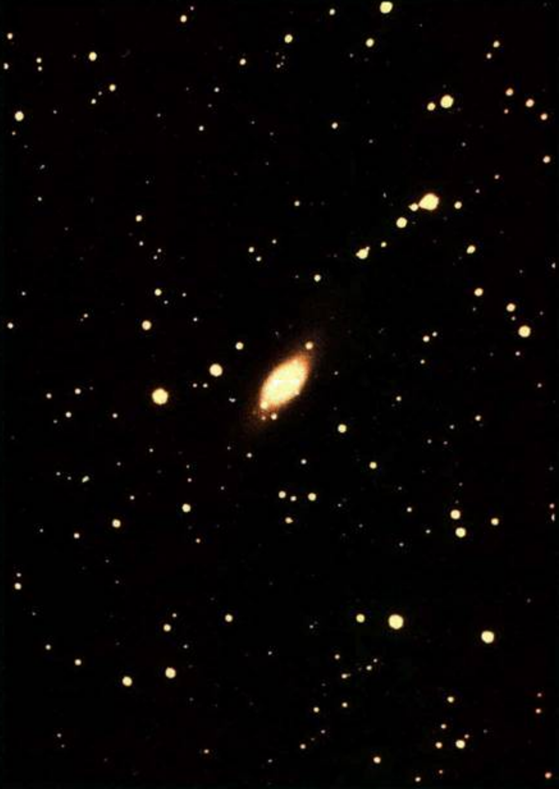
AN ELUSIVE AND PECULIAR NEBULA, NGC 1491 is a gently glowing gas bubble surrounding an 11th-magnitude star. South of NGC 1491 lies the much larger California Nebula.

THE CALIFORNIA NEBULA
John C. Mirtle

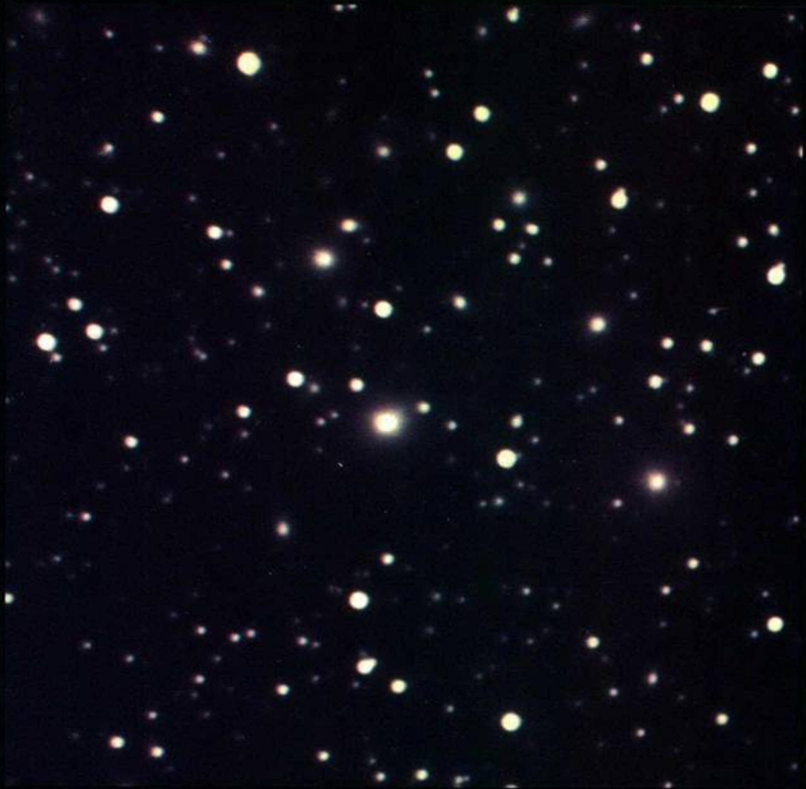
called **Hind's Variable Nebula** (NGC 1554-5), just north of the Hyades. Telescopes reveal a star next to Hind's Nebula. Called T Tauri, this star varies in light output and causes the nebula to vary also.

The brightest star in the sky, Sirius in Canis Major, is itself a stepping off point for finding deep-sky objects. Move your scope 4° south of Sirius and you'll spot **M41** (NGC 2287), one of the prettiest open clusters in the sky. Eight degrees southeast of M41 lies **NGC 2362**, a bright knot of stars surrounding 4th-magnitude Tau Canis Majoris. Should nebulae appeal more to your tastes, try observing **NGC 2359**, a large bubble of gas surrounding a hot Wolf-Rayet star. You can find this nebula 9° northeast of Sirius. NGC 2359 appears as a disk of gently glowing greenish light. You may locate the more challenging **IC 2177** 3° northwest of NGC 2359.

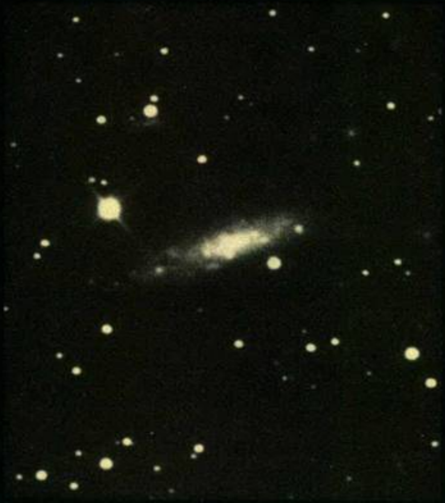
Perseus the Hero completes the winter sky scene. The central stars in this group belong to a cluster called the **Alpha Persei Moving Group**. The more concentrated star clusters NGC 869 and NGC 884, located 10° northwest, form the **Double Cluster**. Small telescopes reveal soft yellow, blue, and orange hues in the cluster's brightest stars. Just $6^1/_2$° northeast of Alpha



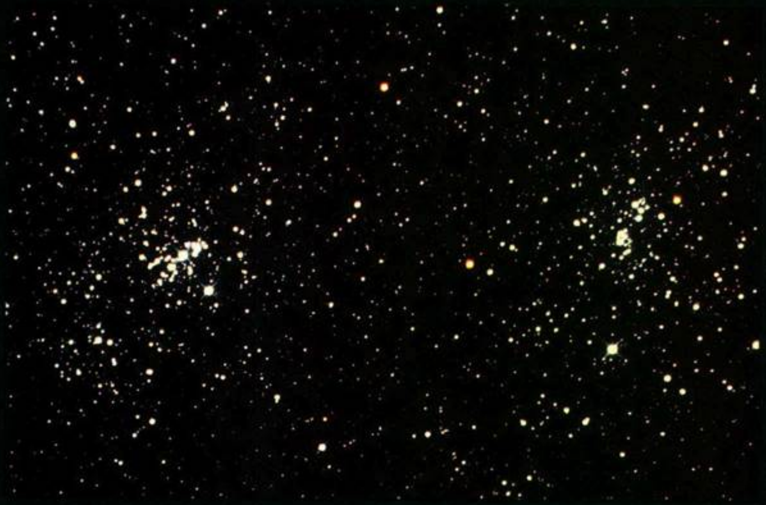
LENTICULAR GALAXY NGC 1023
Jeffrey L. Jones



THE PERSEUS GALAXY CLUSTER
Dave Young



SPIRAL GALAXY NGC 1003
Preston S. Justis



THE DOUBLE CLUSTER
George R. Viscome

Persei you'll find the nebula **NGC 1491**, a small circular fuzzy patch of light surrounding an 11th-magnitude star. The much larger and more challenging **California Nebula** (NGC 1499) lies 15° south of NGC 1491.

Although Perseus lies in the thick of the winter Milky Way, the constellation offers several galaxies that shine through our Galaxy's disk of dust and gas. The first object lies 5$^1/_2$° southwest of Algol (Beta Persei). Visible in a 4-inch scope, the lens-shaped galaxy **NGC 1023** is the brightest of the group. Just 2° north of NGC 1023 you'll find **NGC 1003**, a distant spiral galaxy that is aligned nearly edge-on. As a final challenge, try spotting the **Perseus Galaxy Cluster**, a collection of spirals and ellipticals located 230 million light-years away. Centering your scope 2° east of Algol will show you half a dozen or more tiny, faint patches of light if you're using an eight-inch or larger scope. The most prominent member is NGC 1275, also known as Perseus A.

You can take the easy route during cold weather and loll about on the couch dreaming over pictures of deep-sky objects in ASTRONOMY. Or you can get off the couch and out the door to do some real astronomy. All it takes is some desire, a positive attitude, warm clothing, and maybe a thermos of hot cocoa. □

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Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
Large mounting rings for 80mm Finder	**$55**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$39.50**
1¼" 45° diagonal for correct left-right views	**$52.44**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

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1" long 1¼" OD thread-in extension	**12.00**
2½" long extension (holds 1¼" filters)	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces*	**$26.00**
2" long extension for 2" eyepieces*	**$26.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing,threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

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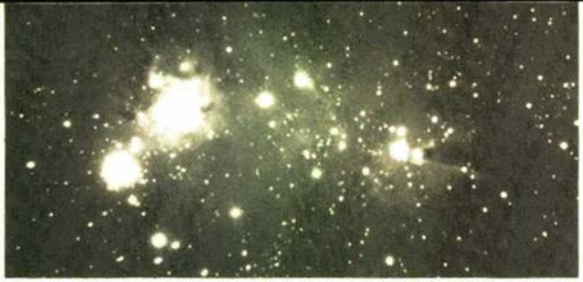
LUMICON carries a full line of telescopes & accessories. Fast delivery, competitive prices.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH



NGC 2264 "The Cone Nebula" in Monoceros. 70 minute photo by Eraldo Guidolin (in Italy) using an 8" f/10 telescope, a LUMICON Cassegrain Easy-Guider at f/6 and hypered 2415 film with a LUMICON Deep-Sky Filter. Mr. Guidolin stated, " . . . Congratulations for your good service and the high quality of your products. With your guider I have taken hundreds of high quality photographs, perfectly guided."

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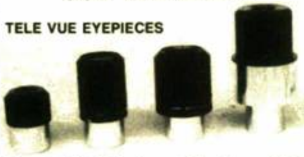
TELE VUE EYEPIECES



Genesis 4" f/5 4 element fluorite	**$1595**
Pronto 70mm f/6.4 apochromat w/2" diagonal	**$698**
Pronto 70mm f/6.4 w/Porro prism	**$649**
Complete Equatorial Mount	**$795**
Motor Drive for above mount	**$198**
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	**$89**
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2" Giant Barlow - 2x	**$189**
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24mm Wide-Field, "superb," 65°	**$169**
32mm Wide-Field, 2" eyepiece, 65°	**$239**
40mm Wide-Field, "awesome," 65°	**$299**
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7mm Nagler, 1¼" eyepiece, 82° field	**$189**
9mm Nagler, 82° field, "the best"	**$219**
11mm Nagler, 82° field, 1¼" or 2"	**$235**
13mm Nagler, 82° field, 1¼" or 2"	**$249**
12mm Nagler, Type II, 82°, 1¼"/2"	**$249**
16mm Nagler, Type II, 82°, 1¼"/2"	**$289**
20mm Nagler, Type II, 82°, 2" only	**$340**
1¼" Paracorr Visual Coma Corrector	**$159**
2" Paracorr Visual Coma Corrector	**$249**
NEW! 22mm Panoptic 1¼"/2", 68°	**$249**
NEW! 35mm Panoptic 2", 68° field	**$325**

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The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$49.00**	**$39.00**
52, 55, 58, 62mm	**$59.00**	**$49.00**
67, 72, 77mm	**$69.00**	**$59.00**
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Hypered 2415 film, 36 exp . . **$10.95, $3/$29**

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LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$35.00**	1.52"	**$39.00**	1.83"	**$45.00**
2.14"	**$59.50**	2.60"	**$75.00**	3.10"	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

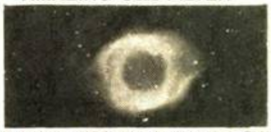
90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$159.00**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

AMAZING OIII FILTER™

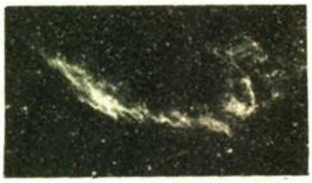


Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for ***reflection*** *nebulae."*
Astronomy, Feb. 1991

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0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
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48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
2" Rear Cell Filter, fits SCT's . . . Deep-Sky, **$119.50** UHC, O-III, H-Beta,	**$199.50**
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48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
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LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** . . . **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines . . . 1¼" **$99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
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Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$20.00**

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DEEP-SKY ASTROPHOTOGRAPHY

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U.S. Patent 4,473,636

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Specify Camera and Telescope type.
U.S. Patent 4,448,500

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Full aperture. Installs in seconds. Specify 2" or 1¼".

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3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**

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Pentax 6X7 **add $119**; Pentax 645 **add $139**

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For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

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Film Type, 35mm	**Exposures**	**Price**
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Fuji HG400 fine grain color neg.	12	**$10.95**
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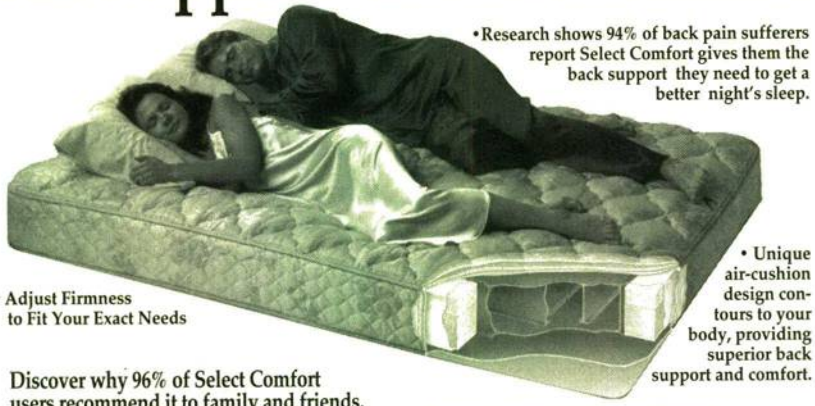

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Discover why 96% of Select Comfort users recommend it to family and friends.

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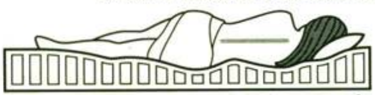
Dr. Connie Horn, M.D., Clarksville, OH



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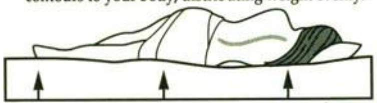

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METEOR MADNESS

Despite a bright Moon that hampered the Perseids and Geminids, 1992 was a great year for meteor observing. The Perseid shower on August 11/12 was unusually active, sending meteors earthward that were visible even in a sky bathed in bright moonlight. The Perseid "microstorm" in fact heralded the return of Comet Swift-Tuttle, the shower's parent comet that had not been observed since 1862. The strong showing of another major shower, January's Quadrantids, left observers meteor happy. And as if to accentuate the meteor madness in a big way, on October 9, 1992, thousands of people witnessed a brilliant fireball that streaked across the east coast and may have ended as a 30-pound meteorite that smashed into Michelle Knapp's 1980 Chevy Malibu in Peekskill, New York.

Over the past several months ASTRONOMY has received more meteor reports than during any other similar period in the past. Many observers watched the Perseids anticipating an active shower, based on speculation that Swift-Tuttle may return. "I coordinated an observing watch with several friends who live in different states," says high school student John Barentine of Phoenix. Barentine and his friends John Moustakas of Carlsbad, California, Benjamin Oppenheimer of Framingham, Massachusetts, and Jason Dickenson of Tallahassee, Florida, watched the shower simultaneously over three nights and plotted numbers of meteors corrected to the zenithal hourly rate (ZHR) to average such factors as observing conditions, latitude, and the altitude of the radiant. "Over 4$^1/_2$ hours on the 11th I saw 51 meteors," reports Barentine, "many of which were bright, yellow in color, and slow as they moved across the sky. Many of them left a perceptible train."

BRIGHT METEORS flashed across the sky frequently during the latter half of 1992. Showers producing favorable shows included the Perseids, Orionids, and Taurids. Russ Sampson photographed this Perseid on August 12, 1992.

Several observers described seeing great fireballs other than the one on October 9. Karen Talbot of Hamilton, Georgia, was disappointed at having been clouded out of the Perseids. On August 23, however, she and her son witnessed "the spectacle of a lifetime." At about 8:30 p.m. EDT the Talbots saw a "brilliant, glowing orange fireball with a train that stretched at least 10 degrees." About an hour later the excited observers saw another bright fireball, this time with a strong pink color and another bright train. "My son now realizes why I plan my life around meteor showers," says Talbot. More than a month later, on September 30, John C. Rice of Columbia, South Carolina, witnessed a brilliant fireball that seemed to be colorless, showed three bright points and smaller particles in between, and took about 15 seconds to cross the sky.

Paul Fischetti of San Jose, California, remembered an old observation of a fireball after reading about last year's events. "On August 23, 1990, I saw an extremely bright fireball from a position east of Sacramento. The meteor streaked from Orion to Ursa Minor and seemed to make a fizzing sound as it went and then a soft pop at its terminus." Have any other readers ever heard a bolide? ☐

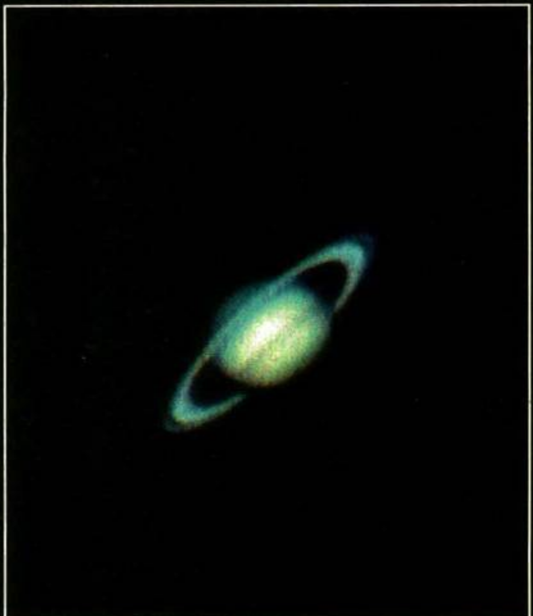
ASTRONOMY wants to hear about your observations of the sky. Please send reports, sketches, and photographs to: David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187.

THE GHOSTLY GLOW OF INTERSTELLAR GAS

The summer Milky Way contains hundreds of pockets of glowing interstellar gas energized by hot stars lying nearby. German astrophotographer Gerald Rhemann's image of the North America and Pelican nebulae in Cygnus (opposite page) wins this month's $100 "Best Astrophoto" award. Rhemann used an 8-inch Schmidt camera and hypersensitized Ektar 25 film, and combined three exposures — 10-minute, 15-minute, and 20-minute shots — into a final transparency.

Reaching far beyond the Galaxy, Kim Zussman photographed the irregular galaxy IC 10 in Cassiopeia, a member of the Local Group of galaxies (left). Canadian astrophotographer Jack Newton recorded the subtle spiral arms of galaxy M74 in Pisces with an SBIG ST-6 CCD camera (below right).

Solar system objects drew attention from observers last autumn. James A. DeYoung and Richard S. Schmidt imaged the long-lost comet Swift-Tuttle on October 20, 1992, using the U.S. Naval Observatory's 24-inch reflector (below left). Another comet, Shoemaker-Levy, graced our skies during the summer. James R. Foster of Hollywood, California, recorded the comet's soft glow on July 28, 1992 (bottom right). When he wasn't busy imaging galaxies, Jack Newton also recorded the subtle colors of the planet Saturn with his CCD camera (bottom left).



COMET SWIFT-TUTTLE glowed at magnitude 6.5 and sported a 2° tail when Michael Stecker photographed it on October 31, 1992.

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6"	135.00	6"	115.00
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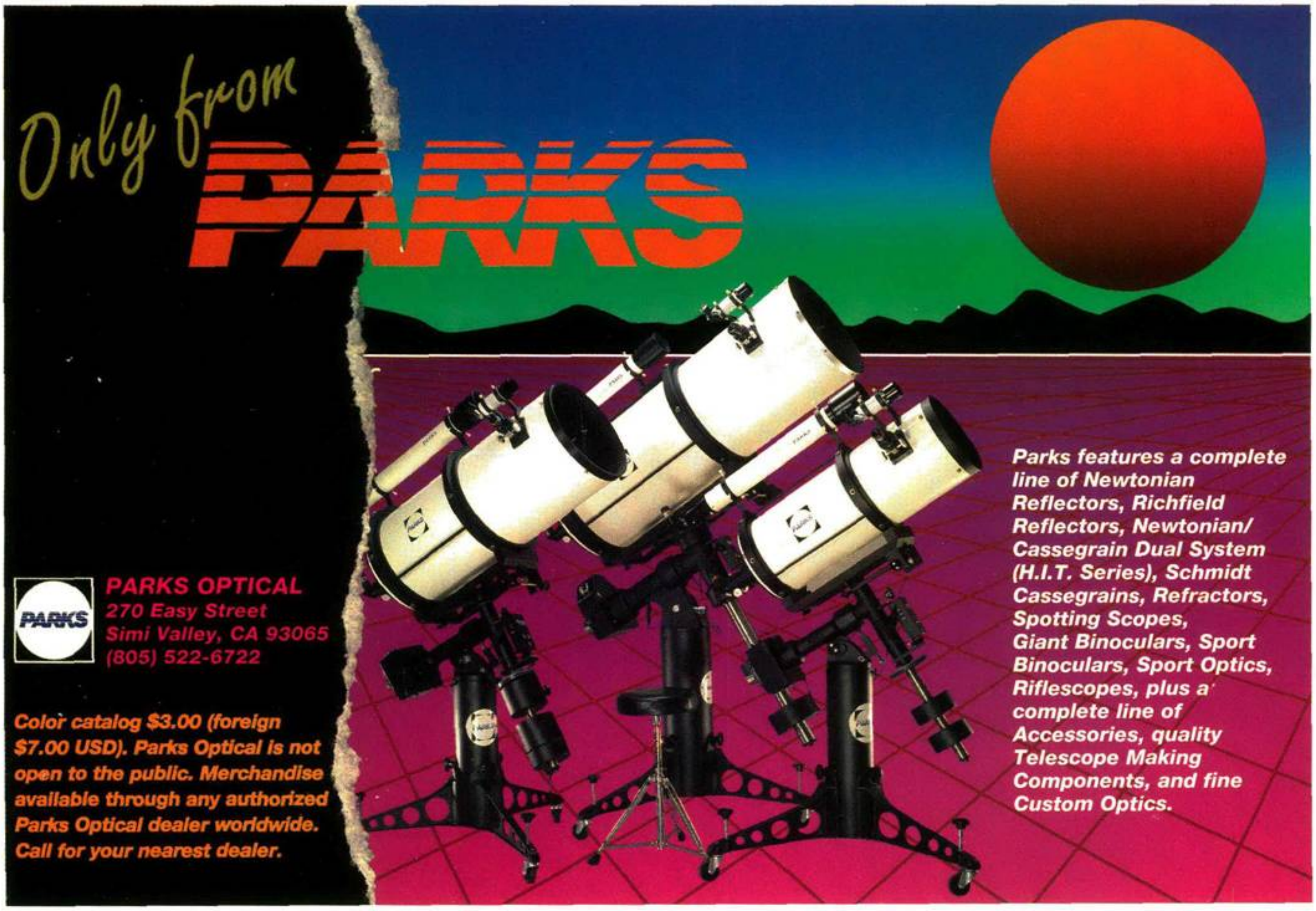

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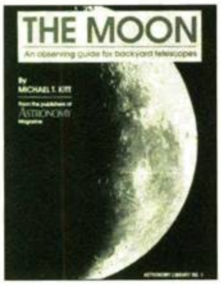

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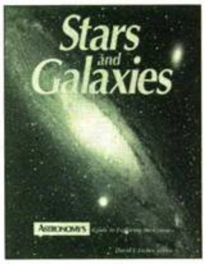

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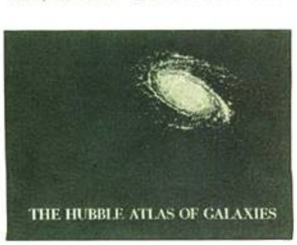

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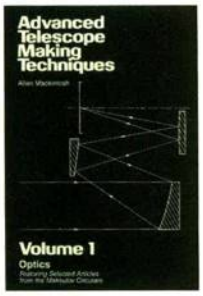

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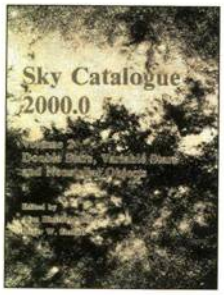

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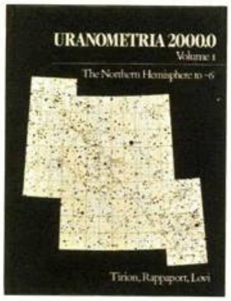

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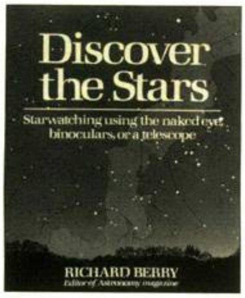
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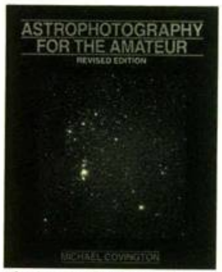

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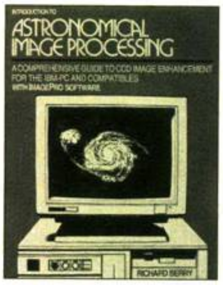
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WANTED — Correspondence with amateur astronomers. Interests: all sciences, art, architecture, design, music, song writing, photography, science-fiction movies. Contact Edward Angley, 2904 Sherman Ct., Mohegan Lake, NY 10547.

FOR SALE — ASTRONOMY from August 1973 to May 1992, complete set, most in binders. $250 plus shipping. Contact Jeff Hubbell, 115 Spencer St., Nangatuck, CT 06770. Phone (203) 729-3812 evenings.

FOR SALE — TeleVue Renaissance refractor with equatorial mount. $995. Contact Omar Zuhdi, 2303 Robinwood Place, Shawnee, OK 74801.

Astronomy Books

NEW ON THE BOOKSHELF

General Interest

Astronomical Calendar 1993, by Guy Ottewell, (Astronomical Workshop, Furman University, Greenville, NC 29613, 1992), 70 pages, paperback, $16.

It's hard to find *one* word to describe Ottewell's *Calendar;* marvelous, educational, illuminating, and classic just seem to scratch the surface. Beginning and veteran observers alike love this book. I consider it a must-have even for armchair astronomers. If you don't have a copy, buy one today.

Ottewell's drawings show not only what you see in the sky but why celestial events appear the way they do. The first part of the book lists events and shows a sky map and horizon maps for each month. The sky maps depict the constellation forms not as stylized figures, but as patterns that you can trace easily in the sky. The horizon maps show the location of the bright planets.

The rest of the book describes the motions of the planetary objects, including the Moon, planets, asteroids, and comets. Ottewell's diagrams showing the motions of the planets and comets alone are worth the price of this book. The book also contains a chart of 1993's meteor showers and a glossary of astronomical terms. — *Dave Bruning*

Star Maps For Beginners, by I.M. Levitt and Roy K. Marshall, (Simon & Schuster, 1992), ISBN 0-671-79187-7, 64 pages, paperback, $10.

This slim, classic work on skylore and learning the constellations first appeared in 1942. Periodic revisions have updated the information on where in the sky to find Venus, Mars, Jupiter, and Saturn. This re-issue for its 50th anniversary includes positions for the bright planets from 1992 to 1997 and a new section on meteor showers.

Cosmology

The Shadows of Creation, by Michael Riordan and David N. Schramm, (W.H. Freeman and Company, 1991), ISBN 0-7167-2366-2, 277 pages, softcover, $11.95.

The Shadows of Creation is now available in paperback. Written in a generally nontechnical style, it describes the structure of the universe and the role that unseen, or dark, matter may play in determining its fate. Also included are descriptions of big bang models and observational tests, inflationary theory, cosmic strings, and other developments of modern cosmology.

Astrophotography

Astrophotography with the Schmidt Telescope, by Siegfried Marx and Werner Pfau, translated by P. Lamble, (Cambridge University Press, 1992), ISBN 0-521-39549-6, 165 pages, hardcover, $59.95.

Marx and Pfau trace the history of the telescope from early 17th-century refractors through telescopes such as the Hubble Space Telescope and detail Bernhard Schmidt's invention of a telescope with a spherical mirror and a correcting lens. They include a short biography of Schmidt.

The majority of the book shows black-and-white images of astronomical objects, such as the Rosette Nebula and the Eta Carinae complex, taken with the Schmidt telescopes at the Karl Schwarzschild Observatory in Germany, the Anglo-Australian Observatory, and the European Southern Observatory in Chile. An essay accompanies each image to explain the nature of the object.

History

The Great Copernicus Chase, by Owen Gingerich, (Sky Publishing Corporation, 1992), ISBN 0-933346-65-4, 304 pages, hardcover, $29.95.

In this collection of 36 essays reprinted from *Sky and Telescope, Scientific American, Atlantic Monthly,* and several other journals and magazines, Gingerich writes about early astronomy, famous astronomers, the history of astronomy, and his global search for copies of Copernicus' great work, *De Revolutionibus.*

Children's Books

Sky Detective, by Eileen Docekal, (Sterling Publishing Co., Inc., 1992), ISBN 0-8069-8404-X, 128 pages, hardcover, $14.95.

Subtitled *Investigating the Mysteries of Space,* Docekal's book provides 12 "cases" or experiments for children to use in exploring the night sky. Over 150 illustrations accompany discussions of the constellations and planets, the lives of stars, and eclipses and other sky events.

Solar System

Exploration of the Solar System by Infrared Remote Sensing, by R.A. Hanel, B.J. Conrath, D.E. Jennings, and R.E. Samuelson, (Cambridge University Press, 1992), ISBN 0-521-32699-0, 458 pages, hardcover, $125.

Aimed at professional scientists, this comprehensive (but pricey) work explains the theory and methods that underpin the use of remote sensing to explore planetary surfaces and atmospheres.

Astrophysics

Annual Review of Astronomy and Astrophysics, volume 30, edited by Geoffrey Burbidge, David Layzer, and Allan Sandage, (Annual Reviews, Inc., 1992), ISBN 0-8243-0939-8, 767 pages, acid-free paper, hardcover, $57.

Noted authorities review 20 areas of astronomy in this annual. Articles include an autobiography by Nobel laureate William Fowler and reports on evidence for black holes, radio emission from normal galaxies, cosmic background radiation, the Pluto-Charon system, and the dynamics of interacting galaxies. This sometimes technical book caters to the advanced amateur and students of astronomy.

Astrophysical Data: Planets and Stars, by Kenneth R. Lang, (Springer-Verlag, 1992), ISBN 0-387-97109-2, 937 pages, acid-free paper, hardcover, $59.

This is part of a three-volume set: this data book on planets and stars, another on galaxies and the universe (not yet published), and a previously published book called *Astrophysical Formulae,* which cites the equations and physics that describe the universe.

Astrophysical Data has lots of tables. The planetary tables include physical characteristics of planets, planetary atmospheres, rings, satellites, minor planets, and comets. The major part of the book describes the Sun, basic stellar characteristics, bright and nearby stars, stellar activity, star clusters, gas and dust clouds, endpoints of stellar evolution, interacting binaries, and supernovae. Positions are given for most of the objects, including both equatorial coordinates (right ascension and declination) and galactic coordinates. Unfortunately many of these are epoch 1950.0 or, worse, unstated as to epoch.

Major errors exist in some of the tables. For example, the table of brightest stars lists Alpha Centauri at a distance of 0.41 light-years instead of 4.35 light-years. And the absolute magnitudes of the brightest stars have errors as large as 17 magnitudes. If errors are prevalent in a table as fundamental as this, what errors lurk elsewhere? I was also puzzled by Lang's use of light-years as the unit of distance for the brightest stars and parsecs almost everywhere else.

Lang includes hard-to-find tables about open and globular clusters, emission nebulae, white dwarfs, RS Canum Venaticorum binaries, supernova 1987A, supernova remnants, and a compilation from Gliese's *Catalog of Nearby Stars.* These tables alone are worth the price of this book. But wait until the publisher releases a corrected edition. Then you should find a place on your desk for *Astrophysical Data* right next to your other often-used reference books. — *Dave Bruning*

Other Books Received

Observational Tests of Cosmological Inflation, edited by T. Shenks, A.J. Banday, R.S. Ellis, C.S. Frenk, and A.W. Wolfendale, (Kluwer Academic Publishers, 1991), ISBN 0-7923-1431-X, 483 pages, acid-free paper, hardcover, $134. Technical symposium.

The Physics of Star Formation and Early Stellar Evolution, by Charles J. Lada and Nikolaos D. Kylafis, (Kluwer Academic Publishers, 1991), ISBN 0-7923-1349-6, 746 pages, acid-free paper, hardcover, $194. Technical symposium.

Stellar Astrophysics, edited by R.J. Tayler, (Institute of Physics Publishing, 1992), ISBN 0-7503-0200-3, 356 pages, hardcover, $75. Reprints from *Reports on Progress in Physics* including articles on the physics of white dwarfs, type I supernovae, s-process nucleosynthesis, SN 1987A, and neutrino astronomy.

Observational Astrophysics, edited by R.E. White, (Institute of Physics Publishing, 1992), ISBN 0-7503-0201-1, 358 pages, hardcover, $75. Reprints from *Reports on Progress in Physics* including articles on planetary nebulae, masers, intergalactic matter, active galactic nuclei, detecting high-redshift galaxies, and large-scale motions in the universe.

High Energy Astrophysics, volume 1, second edition, by M.S. Longair, (Cambridge University Press, 1992), ISBN 0-521-38374-9, 418 pages, hardcover, $69.95; ISBN 0-521-38773-6, softcover, $34.95. Advanced undergraduate or graduate level text.

The Observation and Analysis of Stellar Photospheres, by David F. Gray, (Cambridge University Press, 1992), ISBN 0-521-40320-0, 452 pages, hardcover, $100; ISBN 0-521-40868-7, softcover, $49.95. Graduate level text. □

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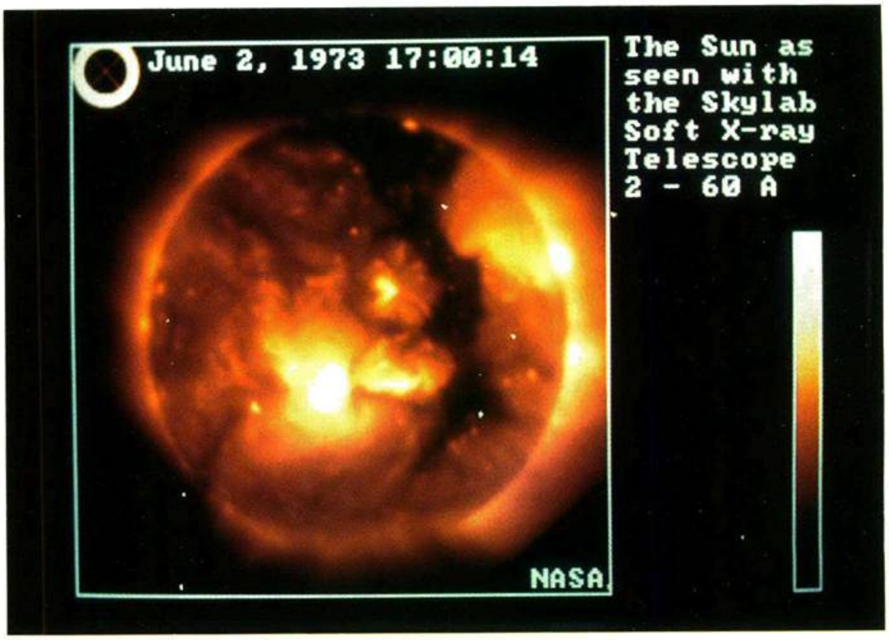
June 2, 1973 17:00:14
The Sun as seen with the Skylab Soft X-ray Telescope 2 - 60 A
NASA

ASTRONOMY: Darla Gawelski

***Skylab Image Display Demo**, Dataset 73-027A-05G, National Space Science Data Center, Code 633.4, NASA Goddard Space Flight Center, Greenbelt, MD 20771. Phone (301) 286-6695. $9, plus $2.50 for shipping and handling. Minimum requirements: IBM PC-compatible computer and 256-color VGA display. One image requires the SuperVGA 1024-768 mode for viewing. Macintosh users can import the images into various graphics programs.*

Do you want to know what the Sun looks like in X rays or want some images to use in an image-processing program? Or perhaps you're looking for a different computer display for Astronomy Day. Sample these images taken by the Skylab X-ray telescope in 1973 and 1974. About 10 percent of the photos taken with the telescope were digitized and stored on magnetic tape. Recently the National Space Science Data Center acquired copies of these tapes, making 1,471 images available to researchers. To show these images, NASA has produced a disk that includes false color X-ray images, enhanced images, a pair of images showing the Sun three days apart, and a pair separated by one solar rotation (roughly 25 days). C-language source code is included with the display programs.

Another demo disk contains an image taken by the soft X-ray telescope aboard the Yohkoh spacecraft on October 25, 1991. The disk is 91-062A-02A and costs $9, plus $2.50 for shipping and handling. It includes programs for displaying the Yohkoh image. — *David Batchelor, NASA Goddard Space Flight Center*

***Epoch 2000**, Farpoint Research, 10932 Hasty Avenue, Downey, CA 90241-4026. Phone (310) 861-6606. $329. Minimum requirements: 80286-based computer, DOS 3.0 and Windows 3.X, 640 KB memory, 5 MB of available hard disk space, and EGA display. Super VGA display, 80386-based computer, math coprocessor, mouse, and 4 MB memory are recommended. Epoch 2000 can use any printer that Windows supports. Both 5¼" and 3½" diskettes are provided.*

This Windows-based program combines a desktop planetarium with image processing. It displays over 45,000 stars, 7,500 named and unnamed minor planets, 600 comets, and 13,000 clusters, nebulae, and galaxies. You can view the sky from any point on Earth at any time between 4713 B.C. and A.D. 10,000 Another feature is the ability to process images, including merging tricolor images into a full-color image. Sample images provided with the program are from NASA, Keck telescope, and other professional observatories. Input image formats include TIFF, FITS, BMP, LNX, ST4, and ST6. Epoch 2000 saves images in TIFF, FITS, and BMP formats.

***PC-SKY**, CapellaSoft, P.O. Box 3964, La Mesa, CA 91944. Phone (800) 827-8265. Introductory price $99, plus $5 shipping in U.S. and Canada and $20 elsewhere. Minimum requirements: 80286-based computer, DOS 3.3, 640 KB memory, high-density floppy drive, 3.5 MB of available hard disk space, and VGA display. A math coprocessor, SuperVGA, and mouse are recommended. Specify whether 5¼" and 3½" diskettes are needed.*

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***BatchPIX,** Richard Berry, Route 1 Box 58A, Cedar Grove, WI 53013. Phone (414) 285-3305. $29.95. Minimum requirements: IBM PC-compatible computer and 3.5 MB of available hard disk space. A math coprocessor is recommended.*

BatchPix permits batch processing of up to 255 CCD images from ST4, Electrim, and Lynxx cameras. You can flat field, scale, mask, filter, center, rotate, translate, zoom, flip, and flop any image and then save the processed image in either the camera format or as a TIFF-format file. The program also displays the image for your inspection or you can choose the movie mode to view a sequence of images.

***ColorPIX,** Richard Berry, Route 1 Box 58A, Cedar Grove, WI 53013. Phone (414) 285-3305. $29.95. Minimum requirements: 80386-based computer, SuperVGA (640x480, 256 color mode), and 3.5 MB of available hard disk space. A math coprocessor is recommended.*

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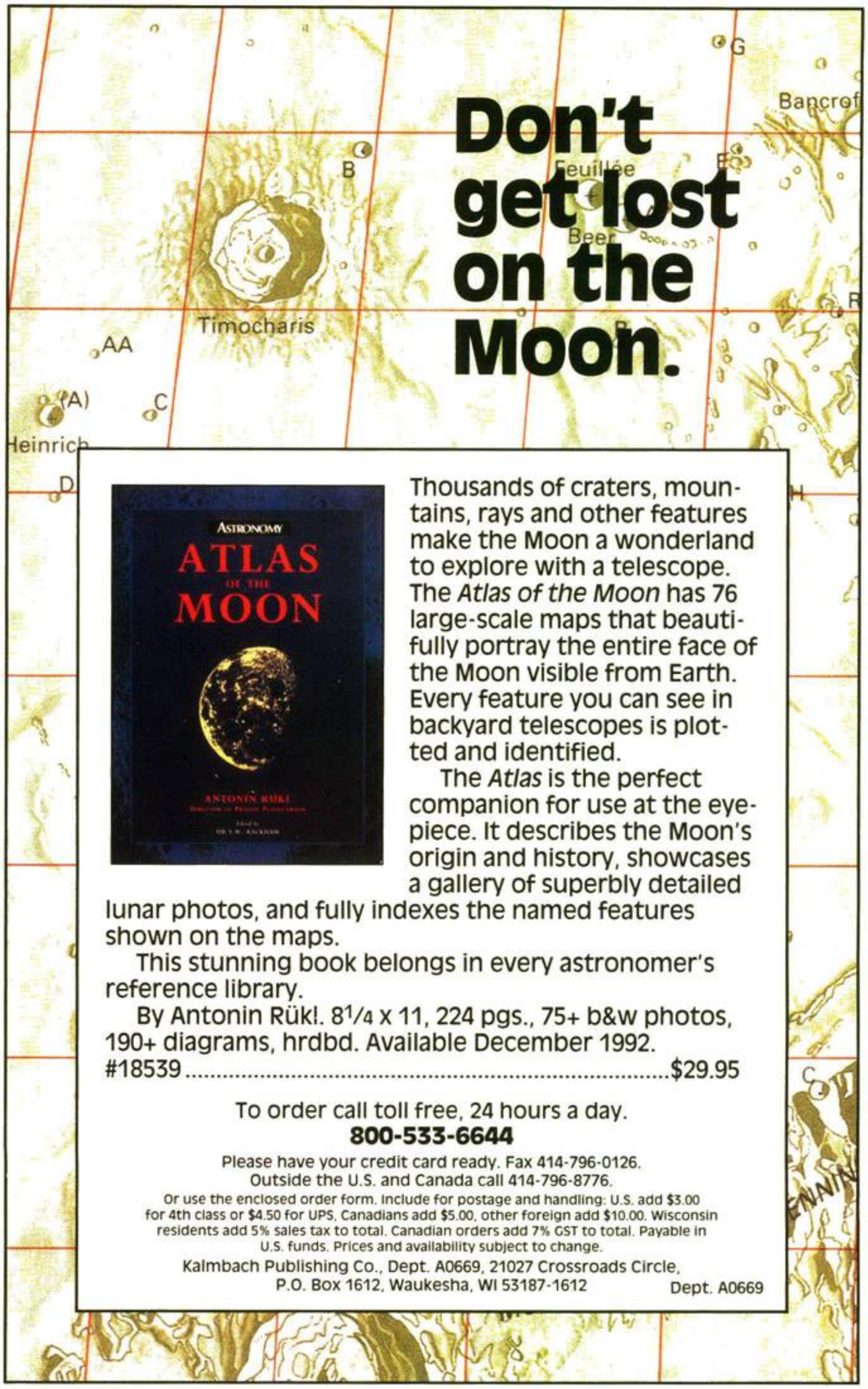

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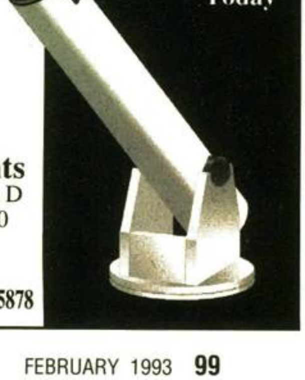

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saved in the TIFF format. ColorPIX requires calibrated (flat field, dark frame, and contrast corrected) CCD images, as provided by BatchPIX or other programs.

Observer's Companion and Stars8.0, *ARC Science Simulations, P.O. Box 1955, Loveland, CO 80539. Phone (800) 759-1642. $50 for registered users of Dance of the Planets, includes upgrade to Dance version 2.5s; $75 for owners of Dance version 2.3 or earlier. Specify whether 5¼" and 3½" diskettes are needed.*

These two extensions to Dance of the Planets increase the capabilities of the sky simulator. Stars8.0 extends the star database down to 8th magnitude, increasing the number of stars from 9,097 to about 45,000. The Milky Way becomes better defined with the larger star catalog. In addition, a click-on data box provides information about each star and an improved printing capability produces higher quality star charts.

Observer's Companion is an on-line almanac that calculates astronomical events over the 10,000-year time range of Dance. It finds eclipses, occultations, conjunctions, risings and settings, lunar circumstances, and more.

SkyGlobe 3.5, *KlassM Software, 284 142nd Avenue, Caledonia, MI 49316. Phone (800) 968-4994 (orders only). Shareware available from CompuServe and other networks; registration fee, $20. Minimum requirements: IBM PC-compatible computer, 470 KB of free memory, and CGA display. A SuperVGA display is recommended.*

SkyGlobe is a planetarium program that displays planets, 25,000 stars, and the Messier objects. You can display star colors or magnitudes, the outline of the Milky Way, and constellation figures and areal outlines. Also, you can display PCX-format images of astronomical objects on SuperVGA displays. No matter what display you have, screen snapshots of star maps are printed in VGA mode for dot Matrix printers and SuperVGA mode for HP-compatible laser printers.

READER'S TIP

William Nielsen of Safety Harbor, Florida, suggests experimenting with the brightness and contrast control of your monitor when looking at the digitized images supplied with some astronomical software. This simple "image processing" can improve the appearance of images that at first look too grainy or contrasty. ☐

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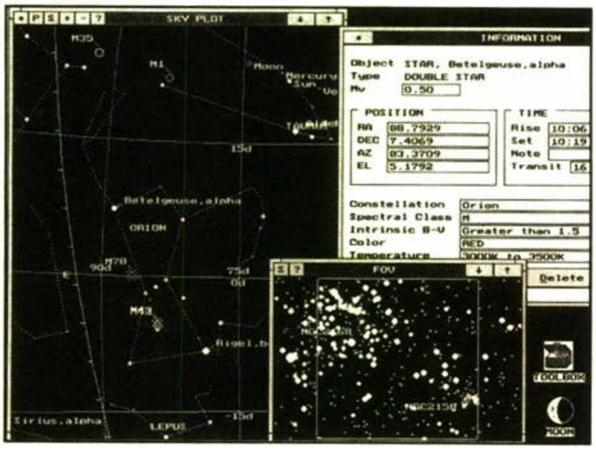

Object STAR, Betelgeuse,alpha
Type DOUBLE STAR
Mv 0.50

POSITION
RA 88.7929
DEC 7.4069
AZ 83.3709
EL 5.1792

TIME
Rise 10:06
Set 10:19
Note
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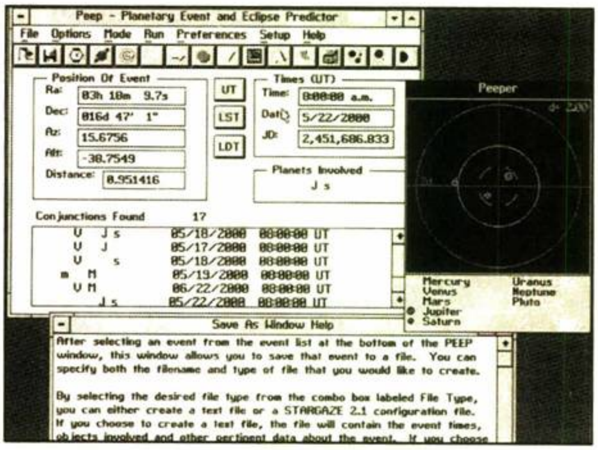

Position Of Event
Ra: 03h 18m 9.7s
Dec: 016d 47' 1"
Az: 15.6756
Alt: -30.7549
Distance: 0.951416

Times (UT)
Time: 0:00:00 a.m.
Date: 5/22/2000
JD: 2,451,686.833

Planets Involved
J s

Conjunctions Found 17

```
   V   J s       05/18/2000  00:00:00 UT
   V   J         05/17/2000  00:00:00 UT
   V     s       05/18/2000  00:00:00 UT
 m   M           05/19/2000  00:00:00 UT
   V M           06/22/2000  00:00:00 UT
       J s       05/22/2000  00:00:00 UT
```

After selecting an event from the event list at the bottom of the PEEP window, this window allows you to save that event to a file. You can specify both the filename and type of file that you would like to create.

By selecting the desired file type from the combo box labeled File Type, you can either create a text file or a STARGAZE 2.1 configuration file. If you choose to create a text file, the file will contain the event times, objects involved and other pertinent data about the event. If you choose

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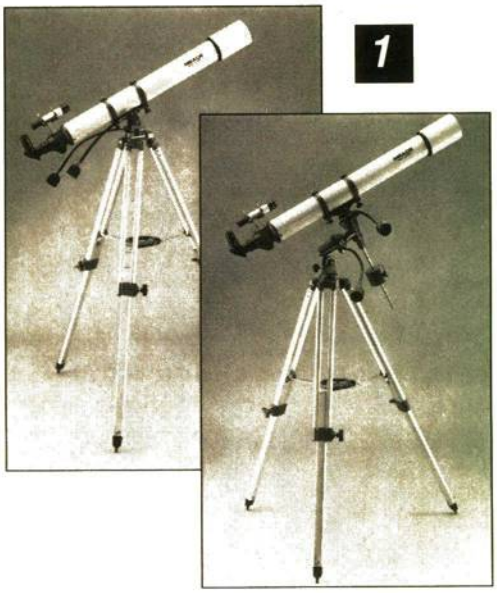

1

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Meade has introduced two 90mm f/11 achromatic refractors. The Model 390 features an altazimuth mount with slow-motion controls on both axes. The Model 395 features an equatorial mount with dual-axis slow-motion controls and setting circles. Both mounts employ an all-aluminum field tripod. Both telescopes include a multi-coated air-spaced objective lens, 1¼-inch rack-and-pinion focuser, 6x30 finderscope, star diagonal, and 25mm (40x) Modified Achromatic eyepiece.

Meade Instruments Corporation, 1675 Toronto Way, Costa Mesa, CA 92626, (714) 556-2291, FAX (714) 556-4604. Model 390: $499; Model 395: $599.

2

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Obsession Telescopes, 923 Stoney Road, Lake Mills, WI 53551, (414) 648-2327. $3,895 plus crating and shipping.

3

New Celestron Accessories

The Quick Release Finder Bracket (bottom) is designed for 8x50 finderscopes mounted on any C8 or C11 optical tube. The bracket allows the finder to be removed and put back with no tools and without losing alignment. (Finderscope shown not included.) The Deluxe Tele-Extender (top) is designed for Schmidt-Cassegrain telescopes and allows the use of 1¼-inch eyepieces with large-diameter barrels for eyepiece projection photography.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (310) 328-9560, FAX (310) 212-5835. Quick Release Finder Bracket: $70; Deluxe Tele-Extender: $70.

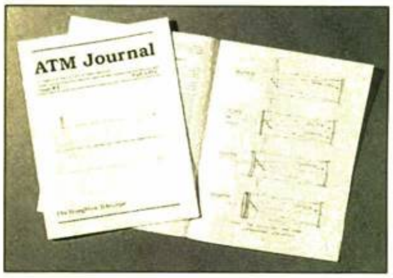
4 Camera Adapter from Tele Vue

The Eyepiece Projection Adapter allows high-power photography of the Sun, Moon, and planets. The two-piece computer-machined adapter is black anodized and contains anti-reflection threads. It accommodates 1¼-inch-diameter eyepieces and can be used on any telescope with either 1¼- or 2-inch focusers. Pictured with the Projection Adapter are optional extension tubes that may be needed to reach focus with some telescopes.

Tele Vue Optics, 100 Route 59, Suffern, NY 10901, (914) 357-9522. Eyepiece Projection Adapter: $95; 2-inch Extension Tube: $40; 3-inch Extension Tube: $40.

5 New Magazine for Amateur Telescope Makers

The new *ATM Journal* magazine is a quarterly publication devoted to articles about designing and making homebuilt telescopes. Developed by the Amateur Telescope Makers Association, a non-profit organization, the new magazine is designed to serve as a forum for telescope makers and opticians. Issue #1 (Fall 1992) features articles about the Houghton-Cassegrain reflector and Shupmann refractor designs, comparisons of unobstructed reflectors, and a homemade 17.5-inch binocular scope.



Amateur Telescope Makers Association, 17606 28th Avenue SE, Bothell, WA 98012, (206) 481-7627, FAX: (206) 281-4921. One-year subscription: $20; outside the U.S.: $30 in U.S. funds.

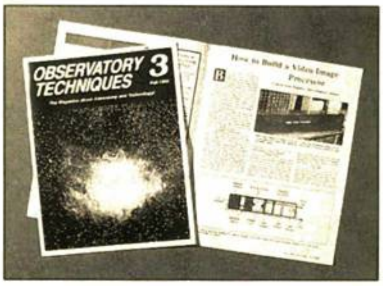
6 Color CCD Imager

Electrim Corporation has introduced a high-resolution color imager to their line of CCD cameras. The new EDC-1000C connects to an IBM PC/AT, PS/2 Model 25 or 30, or compatible computer, digitizing images directly into the PC's RAM memory with a color depth of 8-bits each for red, green, and blue. No frame grabber or third-party software is required. Frame size is 751x488 pixels in interlaced mode. The EDC-1000C can take up to 3 to 5 frames per second in "live" mode. TIFF, PCX, or Targa files can be saved for use by image-processing programs.

Electrim Corporation, P.O. Box 2074, Princeton, NJ 08543, (609) 683-5546, FAX (609) 683-5882. $950.

7 *Observatory Techniques* Magazine

This new quarterly publication focuses on amateur astronomy equipment and techniques. Each issue features hints, how-to articles, and equipment reviews. Topics include CCD cameras, astrophotography, backyard observatories, video imaging, image processing, and the use of computers in amateur astronomy. Issue #3 features articles on using an ST-4 autoguider, building a video image processor, buying vintage telescopes, as well as hardware and software reviews.



Observatory Techniques, 1710 SE 16th Avenue, Aberdeen, SD 57401. One-year subscription: $16; Canada and Mexico: $22 U.S. for surface mail, $24 for air mail; Overseas: $24 U.S. for surface mail, $38 U.S. for air mail.

FOR SALE — Thomas Mathis C-11 fork arms. Heavy-duty machined castings. Tangent arm and dec. motor with bracket. Bolts directly to C-11 or C-14 drive base. Ideal for custom fork mounts. $325. Contact Don Pflanzer, 301 G St., #5, San Rafael, CA 94901. Phone (415) 453-9863.

WANTED — Sixteen-year-old amateur astronomer seeks correspondence worldwide. Interests include astronomy, cosmology, particle physics, computers, and astronautics. Contact Fernando Felix Gutiérrez Blanco, C/Alonso de Ojeda No. 15, 5C, 33208 Gijón, Asturias, SPAIN.

FOR SALE — Celestron 90mm with factory dew cap, erect image viewfinder, 45° diagonal, 30mm Kellner. $349. Phone (215) 287-7716.

FOR SALE — Unused dry-ice cold camera for 35mm film. Fits 2" focuser with shutter cable. Contact Al Kiel, 1424 Kennewick Ave. NE, Renton, WA 98056. Phone (206) 255-2643.

ANNOUNCEMENT — Ancient City Astronomy Club meets first Friday, 8 p.m., First United Methodist Church at King and Riberia streets in St. Augustine. Contact A.C.A.C., P.O. Box 546, St. Augustine, FL 32085-0546. Phone (904) 797-5704 or (904) 471-3054.

WANTED — Amateur astronomer seeks correspondence with people having practical experience with apochromatic refractors. Contact Witold Trusz, ul. Wyszynskiego 13/31, 32-500 Chrzanow, POLAND.

FOR SALE — Complete set of Astronomy, August 1973 through 1990 (209 issues). $250 plus shipping, or offer. Contact Art Heusinkveld, 3350 Adel St. SE, Cedar Rapids, IA 52403. Phone (319) 363-4557.

WANTED — Info about July 1991's solar eclipse in Hawaii for study regarding effects of Moon's shadow on local weather. Need photos and videotapes of sky and Earth during eclipse and data on winds, cloud cover, and temperatures. Will pay, but send description first. Contact Charles C. Whittle, Rt. 3, Box 1667, Pell City, AL 35125.

WANTED — Twenty-five-year-old male seeks correspondence with women interested in science-fiction books and movies, stargazing, and ecology. Contact Scott Mitchell, P.O. Box 740-229095, London, OH 43140.

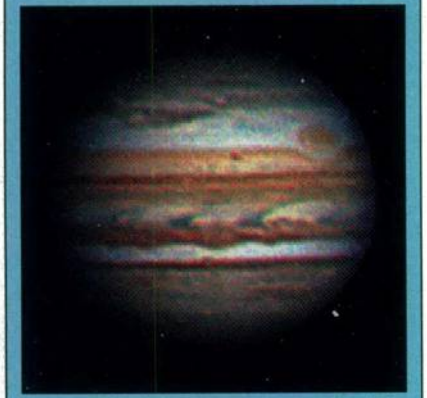
WANTED — Photographs or negatives of light pillar phenomenon. Indicate data: city and state where taken, date, time, weather conditions. Include address for return of photos. Contact Sharon O'Neill, 325 Highland Rd., Pittsburgh, PA 15235-3012.

FOR SALE — Various issues of *Sky & Telescope* from 1989 through 1991. $1 each plus shipping, or trade for *Deep Sky* #1-16 and 26. Will also purchase indicated *Deep Sky* issues. Contact Sharon O'Neill, 325 Highland Rd., Pittsburgh, PA 15235-3012.

Please send Reader Exchange notices to Astronomy Magazine, P.O. Box 1612, Waukesha, WI 53187. Notices can be placed for no charge for non-commercial purposes only. Limit your ad to 40 words, including your name and address. All notices are subject to review, and Kalmbach Publishing assumes no responsiblity for statements made nor for the quality of advertised items. Please allow 6-8 months for it to appear.

COMING IN THE MARCH 1993 ISSUE OF

ASTRONOMY



Don Parker

LOST LAKES OF THE MOON Does water lurk in the perpetually shadowed soil at the bottoms of craters near the Moon's poles?

EVOLUTIONARY SLOWDOWN If humans had evolved 4 billion years later, they would see days and months twice as long as we do now and a Moon so far away it could no longer totally eclipse the Sun.

SHOOTING THE SKY DIGITALLY We'll show you how to get the best images (such as the one of Jupiter above) from the latest CCD cameras.

SURVEYING THE SPRING SKY A crow flies, lions roam, and a water serpent swims in the celestial zoo of spring constellations.

AVAILABLE ON YOUR NEWSSTAND

FEBRUARY 9

8

Helios Motorized Planetarium

Suitable for classroom use, this motorized orrery features planets from Mercury to Saturn that revolve at correct relative speeds around an illuminated Sun, and a Moon that revolves at the correct speed around Earth. The planets can also be manually set for any month and year by means of a degree scale around the rim of the base. The transparent star dome shows the positions of the stars and constellations and plots the ecliptic and lines of right ascension and declination. A 100-page manual is included.

Black Forest Observatory, 12815 Porcupine Lane, Colorado Springs, CO 80908, (719) 495-3828. $595. 50-page catalog available (free in the U.S., $2 Canadian and foreign).

9

Electronic Compass Binocular

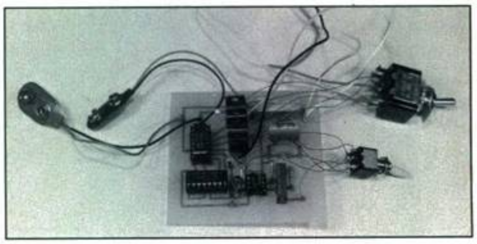
The Commander Electronic is a 7x50 marine binocular that incoporates an electronic compass with readouts visible in the eyepieces. The compass provides accurate bearings even when the binocular is tilted up or down by 20°. The associated electronics provide a memory for nine bearings and the ability to compensate for magnetic deviation so only true bearings are displayed. The binocular is waterproof, shock tested, and comes with a 30-year warranty (one year for electronics).

Steiner Binoculars, c/o Pioneer Marketing and Research, 216 Haddon Avenue, Suite 522, Westmont, NJ 08108, (609) 854-2424. $1,899.

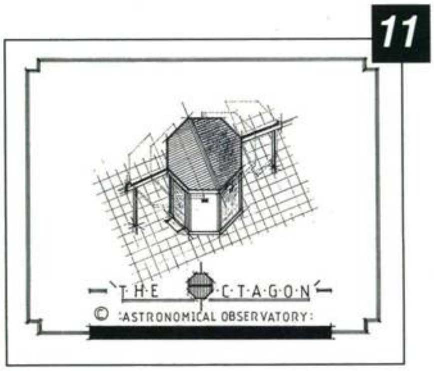
10

Stepper Motor Controller Card

Do-it-yourselfers can motorize equatorial mounts or homemade camera trackers using this controller card. The circuit will operate a unipolar stepper motor and provides two speeds, forward and reverse. It allows the user to set the tracking rate and features a blinking LED to indicate the circuit is operating. Instructions are included with the kit version. A 5-volt stepper motor with 200 steps per revolution and 53-ounce inch of torque is available as an option.



TELSTAR, 2130 Primate Road, Mississauga, Ontario, Canada L4Y 1V4. Logic card kit: $24.95 U.S.; assembled and tested: $44.95 U.S.; optional stepper motor: $30 U.S.



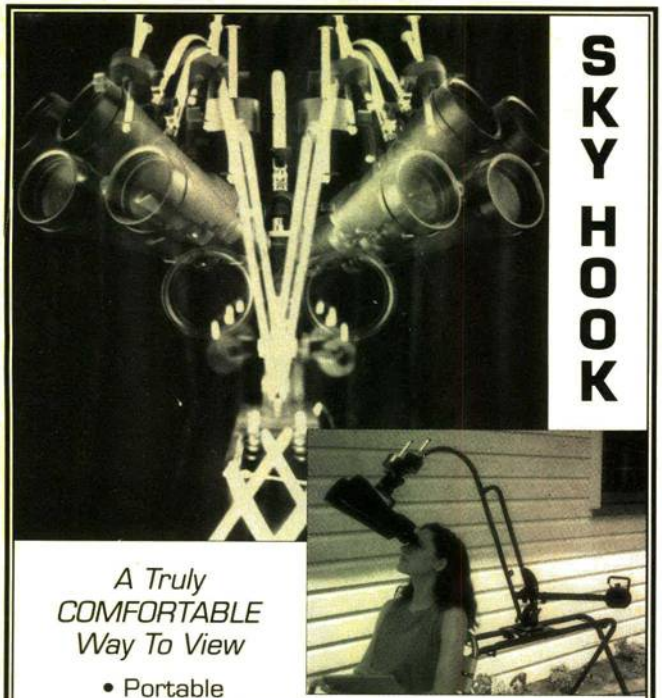
11

Observatory Plans

Donald Abbes, an amateur astronomer in Australia, is making available professionally drafted construction plans for this octagonal observatory. The design features sliding roof segments that can be fully opened for 360° panoramic views or partially closed for wind and stray light protection. The observatory is designed to be easily dismantled and re-erected.

Donald Abbes, 2 Gymea Court, Keyborough, Victoria, Australia 3173, Phone: (03) 798-6275. $23 Australian plus $2 postage and handling.

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.



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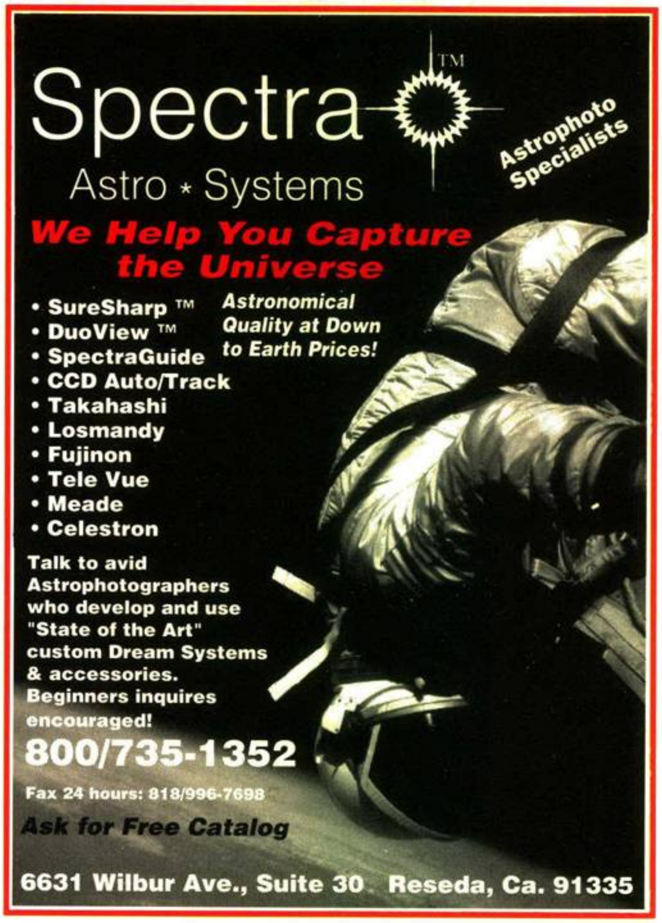

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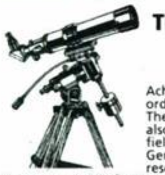

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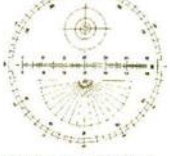

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Readings & Credits

Have Astronomers Solved the Quasar Enigma? (page 28)

The Red Limit, second edition, by Timothy Ferris (Quill, 1983). Relates the early work by Maarten Schmidt and others in the 1960s when they discovered quasars are distant objects.

Colliding Galaxies, by Barry Parker (Plenum Press, 1990). Describes observations and computer simulations of galaxy collisions and mergers.

"The Emerging Picture of Quasars," by Belinda J. Wilkes, ASTRONOMY, December 1991. Discusses how black holes produce the radiation emitted by quasars.

All in the Family (page 36)

Introduction to Asteroids, by Clifford Cunningham (Willmann-Bell, 1988). An excellent survey of asteroids written for lay readers.

Asteroids II, edited by Richard Binzel, Tom Gehrels, and Mildred Matthews (University of Arizona Press, 1989). The latest technical survey; contains several more accessible review papers; massive and thorough.

How We'll Fix Hubble (page 42)

Alice and the Space Telescope, by Malcolm Longair, (Johns Hopkins University Press, 1989).

The Space Telescope: A Study of NASA, Science, Technology, and Politics, by Robert W. Smith, (Cambridge University Press, 1989).

The Space Telescope: Eyes Above the Atmosphere, by George Field and Donald Goldsmith, (Contemporary Books, 1989).

Each of these titles provides good background information on the development and mission of the Hubble Space Telescope but each was published before the optical flaw was discovered.

"Hubble's Optical Fix," by the Space Telescope Science Institute, ASTRONOMY, November 1990. A first report on the optical problem.

Cover: Bob Eggleton; ***p. 4:*** © 1984 Anglo-Australian Telescope Board; ***p. 20, top:*** NASA; bottom: University of Notre Dame; ***p. 21:*** Mark H. Anders, Lamont-Doherty Geological Observatory; ***p. 22:*** William Romanishin, University of Oklahoma; ***p. 23:*** James Beletic, Georgia Institute of Technology; ***p. 24:*** Terry Atwood; ***p. 26:*** Donna Weistrop, University of Nevada, Las Vegas; ***pp. 28-29:*** illustration by Joe Bergeron; ***pp. 30-31:*** illustrations by Phil Kirchmeier; ***p. 31:*** E. Shaya, D. Dowling, and NASA; ***p. 32:*** illustration by Tom Hunt; ***pp. 33-35:*** illustrations by Phil Kirchmeier; ***p. 33:*** David Sanders, image taken at Palomar Observatory; ***p. 34:*** Robert McClure, Dominion Astrophysical Observatory; ***p. 35:*** © Anglo-Australian Telescope Board; ***p. 36-37:*** Arthur Blake; ***p. 38-39:*** D. Durda; ***p. 41:*** JPL/NASA; ***p. 42-43:*** Scott Kahler/Ball Corporation; ***p. 44:*** Bob Hanisch/Space Telescope Science Institute; ***p. 45:*** Tom Hunt after Space Telescope Science Institute; ***p. 46:*** Tom Hunt after Ball Corporation, inset image: Space Telescope Science Institute; ***p. 47:*** Ball Corporation; ***p. 49:*** NASA/Marshall Space Flight Center; ***p. 57, left, middle, right:*** Donald C. Parker on Tech Pan film, September 3, 1988; August 25, 1988; August 21, 1988; ***p. 60:*** Daniel Reilly, 28mm f/2.8 lens, 1/2-second exposure, Ektachrome 200 film pushed to ISO 400, February 2, 1992; ***pp. 61-62:*** illustrations by Phil Kirchmeier; ***pp. 66-71:*** Klaus R. Brasch; ***p. 72:*** illustration by Bruce Bond; ***p. 73-76:*** all illustrations by Phil Kirchmeier; p. 74: Darla Gawelski; p. 76: Bill Iburg; ***p. 78, left:*** Michael Stecker, 8-inch f/4 reflector, Fuji Super HG 400 film, 30-minute exposure; ***right:*** Michael Stecker, 180mm lens at f/2.5, hypersensitized Tech Pan film, 70-minute exposure with a hydrogen-alpha filter; ***p. 79, top left:*** Chuck Vaughn, 350mm lens at f/2.8, hypersensitized Tech Pan film, 60-minute exposure with a hydrogen-alpha filter; ***bottom left:*** Jack B. Marling, 18-inch f/4.4 reflector, hypersensitized Fujichrome 400 film, 20-minute exposure; ***top right:*** Yerkes Observatory; ***bottom right:*** Michael Stecker, 8-inch f/4 reflector, Fuji Super HG 400 film, 45-minute exposure with a Deep Sky filter; ***p. 80, top left:*** Michael Stecker and James R. Foster, 180mm lens at f/2.5, hypersensitized Tech Pan film, 120-minute exposure with a hydrogen-alpha filter; ***bottom left:*** Martin C. Germano, 8-inch f/5 reflector, hypersensitized Tech Pan film, 65-minute exposure; ***top right:*** Ronald E. Royer, 18-inch f/7 reflector; ***bottom right:*** Chuck Vaughn, 14-inch SCT at f/7, hypersensitized Tech Pan film, 60-minute exposure; ***p. 81, top left:*** Thomas L. Dessert, 4-inch f/10 reflector, 103a-F film, 15-minute exposure; ***bottom left:*** Robert C. Bickel, 550mm lens at f/3.6, hypersensitized Konica 3200 film, 30-minute exposure with a Deep Sky filter; ***top right:*** Chris Schur, 12.5-inch f/5 reflector, hypersensitized Tech Pan film, 15-minute exposure; ***bottom right:*** Kim Zussman, 14.5-inch Cassegrain at f/8, hypersensitized Tech Pan film, 120-minute exposure; ***p. 82, left:*** Martin C. Germano, 8-inch f/5 reflector, hypersensitized Tech Pan film, 45-minute exposure; ***right:*** John C. Mirtle, 6-inch f/4.5 reflector, chilled Ektachrome 400 film, 30-minute exposure with a Deep Sky filter; ***p. 83, top left:*** Jeffrey L. Jones, 8-inch f/10 SCT, hypersensitized Tech Pan film, 90-minute exposure; ***bottom left:*** Preston S. Justis, 10-inch f/6 reflector, hypersensitized Tech Pan film, 75-minute exposure; ***top right:*** Dave Young, 18-inch f/4.5 reflector, hypersensitized Tech Pan film, 30-minute exposure; ***bottom right:*** George R. Viscome; ***p. 87:*** Russ Sampson; ***p. 88, top:*** Kim Zussman; ***middle left:*** Richard S. Schmidt, 24-inch reflector, October 20, 1992; ***middle right and bottom left:*** Jack Newton, SBIG ST-6 CCD camera; ***botom right:*** James R. Foster, July 28, 1992; ***p. 89:*** Gerald Rhemann, 8-inch Schmidt, hypersensitized Ektar 25, 10-, 15-, and 20-minute combined exposures; ***p. 98:*** Darla Gawelski; ***p. 112:*** Donald C. Parker.

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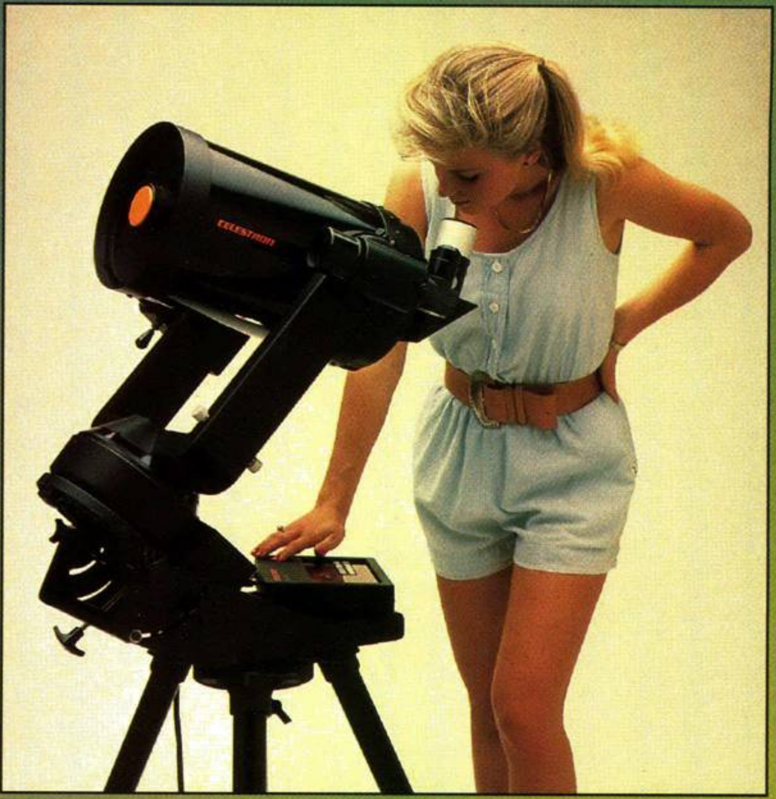

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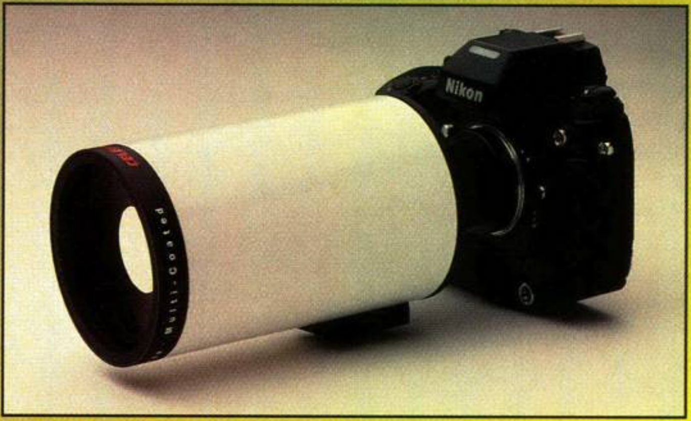

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Meetings & Events

February 15-21
9th Annual Winter Star Party, Camp Wesumkee, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact Bob or Sharon Grant, 5401 SW 110th Avenue, Miami, FL 33165. Phone: (305) 595-8778.

March 17-19
Satellites and Education Conference IV, West Chester University, West Chester, Pennsylvania. Sponsored by the School of Education, NASA, GE Astro Space, Pennsylvania Space Grant Consortium, and the National Oceanic and Atmospheric Administration of the U. S. Department of Commerce. Contact Nancy McIntyre, West Chester University, West Chester, PA 19383. Phone (215) 436-2323.

March 20
2nd Annual Messier Night, Lake Hudson State Recreational Area, Clayton, Michigan. Sponsored by the Astronomical Societies of Lenawee and Hillsdale Counties. Contact the Astronomical Societies of Lenawee and Hillsdale Counties, P.O. Box 229, Hudson, MI 49247. Phone: (517) 448-7173 days or (517) 547-7402 evenings.

April 5-7
Second Solar Astronomy Convention, La Paz, Baja California Sur, Mexico. Sponsored by the La Paz Station of the Solar Astronomy Research Center. Contact Calle La Purisima 119, Colonia Bellavista, C.P. 23050, La Paz, Baja California Sur, Mexico. Phone: 91-682-1-07-32.

April 8-11
Houston Future Fest, Hyatt Regency Downtown, Houston, Texas. The public is welcome at this science fiction convention, but admission to most of the events and activities will require paid registration. Contact Future Fest, P.O. Box 1770, Friendswood, TX 77546-1770. Phone (800) 787-5317.

July 31 - August 2
Stellafane, Springfield, Vermont. Contact Stellafane, P.O. Box 50, Belmont, MA 02178. ☐

Clubs, please submit announcements at least four months before the date of the meeting or event. Readers, when you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

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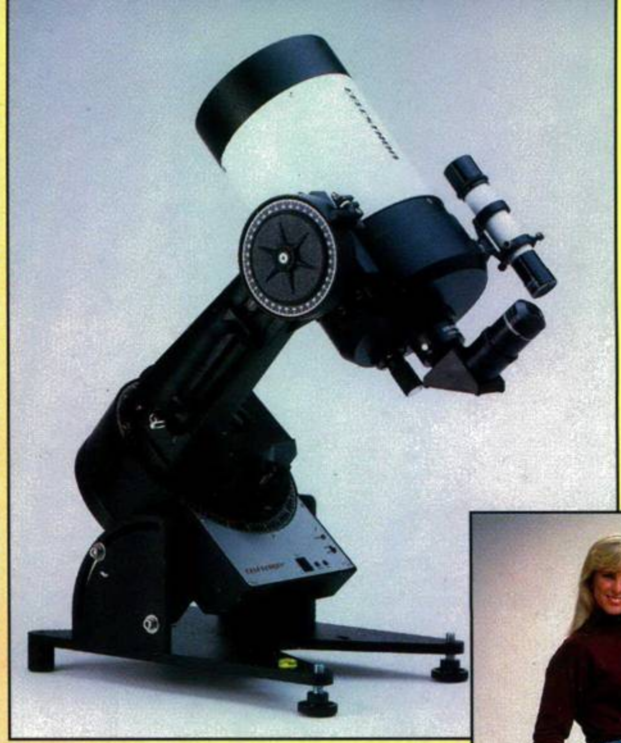

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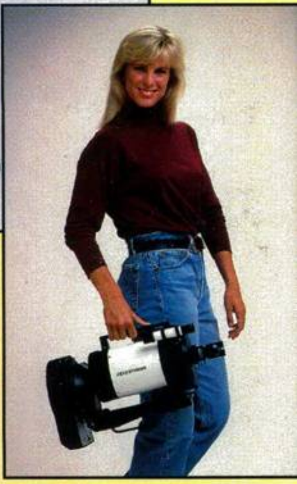

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